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PROJECT SELECTION AND RESEARCH EVALUATION AROUND THE WORLD SINCE 1985

1) Project Selection Methods: International Comparisons
2) Policy Uses of "Evaluation of Research" Literature

Prepared under contract to the Office of Technology Assessment
July 1990

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Project Selection Methods: International Comparisons

Ron Johnston
Techmonitor Ltd.
Technology and Social Change Center
University of Wollongong
Australia

Prepared under contract to the Office of Technology Assessment
June 1990

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THE NATURE OF BASIC RESEARCH

Not so long ago there were two, clearly distinguishable types of research - basic and applied. Basic research was original investigation with the primary aim of a more complete knowledge or understanding of a subject. By definition almost all research in universities was basic. Some research in government laboratories may have been basic, but it would almost never be found in industry.

Applied research, on the other hand was investigation directed towards a particular application. It was the business of industry. Occasionally it was recognised that the results of basic research may have practical application. What followed was applied research.

However, as the scientific world map has become more coherent as a result of the massive investments in research over the past forty years, and as the development and application of knowledge has become an increasingly critical component of international economic competitiveness, there has developed a growing capability, and demand, to steer the processes of research towards generally identified objectives.

Thus Ziman[1] has argued:

> The development of a basic network of reliable concepts over a large area of science (e.g. in molecular biology) makes it possible to envisage a variety of further advances, either of knowledge or of practical application, before they have actually occurred... there is no longer a sharp boundary between academic and applied research. Highly theoretical research might be motivated by 'curiosity' - or it might be undertaken for its potential contributions to practical use. The solution to a problem raised during technological development may have immediate practical value - but it may also be appreciated as a key to further basic understanding. Under these circumstances, the time required to exploit a fundamental discovery can sometimes become so short that industrial firms have to be directly involved in basic research. At the same time, academic scientists are increasingly aware that a new industry might possibly arise out of their work.

Hence, the boundaries between basic and applied research have become increasingly fuzzy. Indeed, the actual concepts themselves are increasingly inadequate to describe the nature and characteristics of contemporary research. One response has been the development of the concept of strategic research. This reflects the increasing links between fundamental knowledge and application as a consequence of which basic research can be directed to wider longer-term goals, such as strengthening the framework of understanding in a key area, or underpinning a generic technology, or creating linkages between independent branches of knowledge e.g. chematronics.

Thus basic research has been subdivided in many countries, at least for statistical purposes, into **strategic basic research**, conducted with an expectation that it will provide a broad base of knowledge necessary as the background for the solution of recognised or potential problems, and **pure basic research**, carried out without looking for long-term economic or social benefits other than the advancement of knowledge.

Strategic research thus sits between basic and applied research. Increasingly however, it is capturing the territory formerly occupied by the others. What this reflects is that all research, however specified, is increasingly shaped by national institutions, structures, policies and practices.

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1 John Ziman, Science in a 'Steady State': The Research System in Transition, London, Science Policy Support Group, 1987), p. 6.

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The brief of this report is to 'identify, catalogue and describe the major methods of selecting basic research institutions, investigators and projects for government support'. For this purpose, 'basic research' will be largely restricted to that research performed in higher education institutions, and government supported centres devoted to research. It will examine 'methods', but include consideration of changing structures that are significantly influencing the process of identifying and selecting basic research for support.

THE INFLUENCE OF NATIONAL INSTITUTIONAL STRUCTURES

The institutional structures of policy-making and funding are critical determinants of the way in which governments support basic research, and provide a powerful context to which any new methods of selection of basic research must be adapted. The reasons for this influence are at least threefold.

Firstly, institutional structures strongly reflect the particular political, economic, and more generally cultural history of a country. While there may be a certain universality in science, this certainly does not carry over to its science policy structures. Thus it is essential for any international comparative study of methods to place the application of these methods in the context of national structures and culture.

A striking example of this is the structural heterogeneity of different national research systems - a heterogeneity which is the outcome of opportunistic historical developments. Thus, as Ziman has noted, in the UK and the USA, it is the department - 'a multifunctional organisational entity responsible for all teaching, research and other activities in a broadly-defined scientific discipline within an HEI'[2] which is the predominant form of research organisation. In contrast, in France with its CNRS laboratories, and in Germany, with the Max Planck Institutes, it is the research institute, staffed by full-time researchers, working in a designated problem or disciplinary area, that is the most common model of research organisation.

Secondly, the particular shape of decision-making structures themselves reflect in part previous processes of selection of basic research. For example, strong government commitments to nuclear power development in the past have led to the establishment of nuclear research institutions which attract a significant level of government funding for basic research. Similarly,

> the Big Sciences such as high-energy physics and astronomy, which were funded generously in the past are now, as a result, well represented on decision-making bodies. There has, therefore, been a tendency for early established sets of priorities and research interests to become 'frozen in' in the decision-making structure.[3]

Thirdly, as noted above, these structures constrain the possibilities for change, and the form and nature of new policy initiatives.

It is important to recognise that there is more than one level of institutional structure involved in shaping decisions about Government support for basic research. Broad questions of objectives

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2 John Ziman, Restructuring Academic Science, (London, SPSG, 1989).

3 John Irvine and Ben R. Martin, "What Direction for Basic Scientific Research", Science and Technology Policy in the 1980s, Gibbons and A. Udgaonkar (eds) (Manchester, Manchester University Press, 1985).

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and economic and social policy are set at the policy level and involve a wide diversity of political and administrative institutions in different countries. At the next level the funding bodies play a central role in establishing the methods for selectively supporting basic research to be performed in the research institutions. However effective implementation occurs at the operational level within the institutions which make up the research system. Thus there is a need to examine the structure and interplay of these three levels of decision-making.

Finally, as we shall see in our examination of the policies and practices in various countries, a significant proportion of the innovations in supporting basic research rely on structural mechanisms rather than new methods. For example, the desire of funding bodies to take a more active role in the steering and structuring of research is leading to the creation of new centres where resources can be concentrated on emerging fields of research

INTERNATIONAL COMPARATIVE STUDY OF SELECTION METHODS

Introduction

Analysis of the major methods of selecting basic research institutions, investigators and projects for government support for each of the nine countries examined is presented in a standard format, covering:

- the culture of basic research funding and management;
- the structure and function of research funding organisations;
- basic research selection methods.

Particular attention has been directed to instances of the use of ex-post evaluation in deciding basic research resource allocation. Where significant allocation decisions are made in research performing organisations, they have been reported.

Table 1 presents a summary of recent approaches adopted in the nine countries examined to more selective support of basic research. In the main (though with the marked exception of the UK), these represent relatively marginal supplements, involving no more than 20 per cent of budget. The predominant form of distribution of funds for basic research remains the response to undirected proposals evaluated by various administrative forms of the peer review process.

Two major vehicles have been identified as being used to influence the direction of basic research. The first of these does not address specific research content, but relies on the effects of increasing the concentration of research resources around high performing individuals or groups.

The second seeks to influence the balance of the national basic research effort through the establishment of national priorities.

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TABLE 1 RECENT APPROACHES TO MORE SELECTIVE SUPPORT OF BASIC RESEARCH

Country/ Agency*	Steering Device	Priority Setting		Implementation/Selection		Status
		Method	Decision-Makers	Methods†	Decision-Makers	
UK						
UFC	Selective core-funding to universities and to departments	-	-	Review of departmental performance against 4 criteria	Council part-time academics) and department officials	Government Appointed
ABRC	Interdisciplinary Research Centres (1988)	Submissions and internal discussion	Panels	Open Proposals	peer panels and referees	"
SERC	Directorates (7 years)	Internal discussion	Council (peers and users)	Open proposals	peer panels and referees	"
	Program (5 years)	Internal discussion	Council	Open proposals	peer panel and referees	"
ESRC	Centres (5-15 years)	Internal discussion	Council (peers and users)	Invited Proposals	Board of peers, and users	"
	Programs (5 years)	Internal discussion	Research Grants Board	Open proposals	Board of peers and users	"
FRG						
DFG	Priority programs	Bottom-up discussion	Researchers	Invited proposals	DFG Senate (peers)	Elected
	Priority research areas	Bottom-up discussion	Researchers	Invited proposals	peer review	"
MPG	Institutes	-	-	Open proposals and extensive evaluation	MPG Senate (peers)	"
FRANCE						
MRT	Programmes Mobilisateurs	Identification of generic technologies	CRE* and department officials	Negotiated proposals	Department officials and peer panels	
CNRS	Annual strategic plans	Identification of leading researchers	Council peers and department officials	Invited proposals	Peer panel and referees	Elected and appointed
JAPAN						
Monbusho	Priority Research Areas (3-6 years)	Identification of areas of strong scientific opportunity & social need	Monbusho Science Council	Open Proposals	Science Council and peer panels and referees	Appointed
	Specially Promoted Research (5 years)	Selection of 2 key fields and program leader	Science Council	Proposal by selected program leader	Science Council	"
NETHERLANDS						
MES	Conditional Funding of university research	-	-	Evaluation of proposed major research programs by experts and bibliometric measures	MES (government department) and advisory panel	"

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Netherlands cont.						
NWO	Second Flow Funding	Identification of future needs and priorities	RAWB * (appointed) and NWO	Open proposals	NWO (peers) and referees	Elected
SWEDEN						
Cabinet	Research Policy Bill	Wide consultation, symposia, reports over 2 years and government department, scientific societies, researchers	Effective consensus	-	-	-
NFR	Consortia	Invitations to consortium of university departments to propose interdisciplinary programs	Council (appointed and elected)	Open proposals	Council andForeign referees	Appointed and elected
FRN	Priority fields	Identification of societal problem, then elaboration of research needs and opportunities	Council and Committees (research and users)	Invited proposals	Council and foreign referees	-
CANADA						
ISTC	Decision Framework for Science and Technology	Computation of agencies' research priorities identifying strengths and gaps	ISTC	-	-	-
ISTC (Innovation)	National Centres of Excellence	-	-	Open proposals judged against criteria of excellence and industrial relevance, and network formation	ICST Committee (government officials and researchers) and national and international referees	Appointed
NSERC	Strategic Grants Program	Identification of 30 themes in the 3 national priority areas by consultation, analysis, workshops	Science Council of Canada	Open proposals	Peer panel and referees	-
SSHRC	Strategic Research Program	Biennial Seminars and commissioned reviews	Council (department officials and researchers)	Open proposals	Peer panel and referees	-
AUSTRALIA						
ARC	Special Research Centres			Open proposals	Peer panels and referees	-
	Priority Research Areas	Submissions consultation and internal	Council (researchers)	Open proposals and competition against all other applications	Peer panels and referees	-
NH&MRC	Priority Research Fields	Internal discussion and consultation	Council (reseasrchers) and poanels	Open proposals	Peer panels and referees	-

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INDIA						
National Development Council	Five-year Science and Technology Plan	Expert reports, consultation, draft reviews	Council (government officials)	-	-	-
SERC	Thrust Area Programs	National exercise of working paper preparation, review, National Seminar	Council and Program Advisory Committees (scientific experts and government officials)	Invited proposals	Council and peer panel and referees	Appointed
	Intensification of Research in High Priority Areas Scheme	Thrust area identification exercise	PACs	Proposals invited from outstanding scientists	Council and peer panel and referees	Appointed

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* UFC Universities Funding Council
ABRC Advisory Board of the Research Councils
SERC Science and Engineering Research Council
ESRC Economic and Social Research Council
DFG Deutsche Forschungsgemeinschaft (German Research Society)
MPG Max Planck Gesellschaft (Max Planck Society)
MRT Ministry of Research and Technology
CNRS Centre National de la Recherche Scientifique (National Centre of Scientific Research)
CPE Centre de Prospective et Evaluative (Prospects and Evaluation Centre)
Monbusho Ministry of Education, Science and Culture
MES Ministry for Education and Science
NWO Netherlands Organisation for Scientific Research
RAWB Science Policy Council of the Netherlands
NFR National Science Research Council
FRN Council for Planning and Coordination of Research
ISTC Industry, Science and Technology Canada
InnovAction Canadian Strategy for Science and Technology
NSERC Natural Sciences and Engineering Research Council
SSHRC Social Sciences and Humanities Research Council
ARC Australian Research Council
NH&MRC National Health and Medical Research Council

† Open proposals - a general call for proposals from all who are eligible, usually with broadly specified criteria for assessment.

Invited proposals - proposals invited from selected individuals or research teams.

Negotiated proposals - identified researchers work closely with research-funding bodies to develop a proposal which meets the requirements.

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The level at which priorities are set varies considerably by country and research agency. Martin and Irvine's[4] analysis of the degree of specificity of research foresight can be applied with advantage to the levels of priority-setting. They identify four levels:

- holistic - concerned with a spectrum of fields; corresponds to priorities at the level of generic technologies such as information technology, biotechnology or general problems such as ageing, or poverty;
- macro - focusses on a limited number of research fields; examples of priority setting are space science, bacterial diseases, robotics, technology and the economy, urban development;
- meso - concerned with a single scientific field or technology; examples of priority setting include solid state physics; biological materials, neuroscience, linguistics;
- micro - at the level of specialities of projects; priority-setting at this level blurs into the traditional processes of selection on grounds of excellence, but can include de-facto priorities achieved by concentrating resources in key individuals or teams.

In general holistic priorities are set by governments and their advisory bodies. Micro priorities are a consequence of the internal operations of proposal evaluation. It is at the macro and meso levels that new approaches to priority-setting have begun to influence the direction of basic research.

UNITED KINGDOM

The three main themes running through the Government's support of civilian science are the importance of maintaining and enhancing quality in science, increasing the economic and social returns from science, and better management through greater concentration and selectivity of science activities. Strenuous efforts have been made to introduce new policies to achieve those objectives.

There is an annual review of Government R&D funding but there is no overall R&D budget. The system is highly decentralised, each Department determining its own R&D programs in the light of its own policy objectives and priorities. Recent decisions to exclude the public funding of near-market research has led to some increase in funds for basic research.

The major source of funds for basic research is the Department of Education and Science (DES). It provides the general support for the Universities' teaching and research through the Universities Funding Council (UFC), formerly University Grants Committee (UGC), and the funding of the five Research Councils, commonly referred to as the science budget. The Councils for Agriculture and Food (AFRC), Economic and Social (ESRC), Medical (MRC), Natural Environment (NERC) and Science and Engineering Research (SERC) provide funds on a competitive basis to university researchers, and in most cases maintain their own research centres. The organisation of Government support for research is shown in Figure 1.

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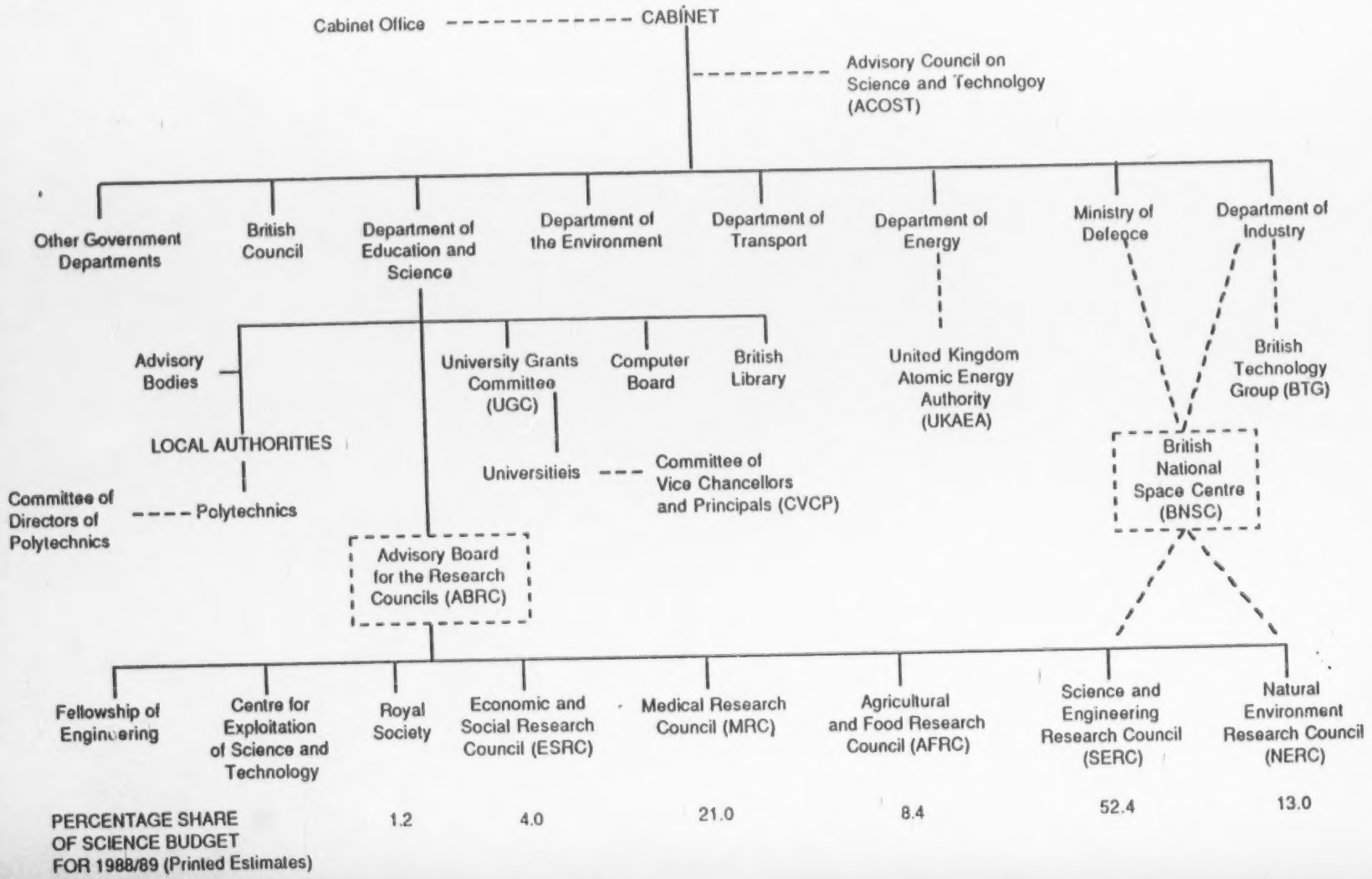
Figure 1 Organisations of Government Support for Scientific Research and Development in the United Kingdom



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The Research Councils have a high degree of autonomy in establishing their own priorities and procedures. However the Advisory Board of the Research Councils (ABRC) plays an important role in advising the DES on the overall budget and on the allocations to the five Councils. In addition the recently established Advisory Council on Science and Technology (ACOST) has a role in setting priorities at a national level.

The block grant to universities distributed by the UFC, one component of which is for the support of research, carries no requirements for expenditure in particular areas or ways. However, since 1986, the UFC has established allocation procedures which incorporate explicit recognition of the research dimension. The formula favours those institutions which, in each of 35 predesignated subject-related cost centres (essentially departments), are judged to have high quality research. The assessment of quality is made in terms of external research income and peer judgements by the relevant UGC sub-committees. However the distribution of its block grant remains the prerogative of each university. In 1989, a second round of cost centre rankings for all the universities, on a scale of 1-5, was published; this contributed to determination of the allocation of resources to universities, and within universities to highly-ranked cost centres.

The UFC has also conducted a series of subject reviews which have led to a rating of all the departments offering these subjects, determination of minimum scale measures for continued existence, differentiation into effectively research and teaching, and teaching-only categories, and consequent differential funding support.

The criteria used to determine ratings were:

- publications;
- success in obtaining research grants and studentships;
- success in obtaining research contracts;
- professional judgement of advisory group and panel members.

The ABRC has initiated or encouraged a number of new procedures in the determination of support for basic research. In 1985 it recommended a set of six criteria to be adopted by the Research Councils in determining funding (excellence, applicability, timeliness, pervasiveness, significance for education and training, and exploitability), which have been applied by some of the Councils.

Two of their initiatives have been relatively effective. The first has been to increase the proportion of funding flowing to 'directed programs' which have increased from 19 per cent to 32 per cent of Council's grants since 1980. These are designed to develop coherent programs of research in selected areas or to stimulate research in fields judged to require more effort in the national interest. More details are provided under the details of the individual Councils. The second initiative has been to increase the proportion of program grants, as opposed to project grants, from 15 per cent in 1980 to 20 per cent in 1989. Program grants are generally larger, support a bigger team of researchers, and last for a longer period (5 years) than project grants.

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Their most recent initiative to achieve purposeful refocussing of research activity, together with the Research Councils, UGC and DES, has been the establishment of Interdisciplinary Research Centres (IRCs). These are funded for six years. Their objectives, as set out below, indicate these are being applied to basic research:

i. greater concentration of research effort, based on existing strengths;

ii. more interdisciplinary working, with the deployment of scientists from a range of disciplines outside the confines of traditional departments;

iii. increased effort in important areas of strategic science, selected with a view to potential exploitability and applicability;

iv. a readier and stronger interface between strategic research in higher education and industry;

v. more positive and purposeful management of research within higher education;

vi. more effective collaboration between higher education institutions and the Research Councils in the deployment of research resources.

Initially (in 1988) a general call was made for suggested candidate fields. These were processed through Research Council committees, made up of eminent researchers, and a number established. More recently, the process has been conducted entirely inside the Councils and committees, with final determination being made by the ABRC. More that 20 fields have been identified as suitable for establishment of IRCs. Once a field has been selected, proposals are called for and evaluated by the committee-based peer review process. One feature of the IRCs is that they will be subject to a minor review after two years and a major review after four years to determine if funding should continue.

The Economic and Social Research Council (ESRC), which is the smallest of the research councils, has made major changes to its methods of operation in recent years, introducing structured procedures for planning and evaluation. Until the end of 1987, there were ten discipline-based committees responsible for funding research. These committees acted in both responsive and initiating modes, receiving unsolicited applications for grants and advertising for proposals in areas of their own choice. They were largely autonomous, with the Council exercising little control or coordination.

There is now a Research Grants Board, responsible for assessing and funding applications received in the Council's responsive mode and three Research Development Groups (one each for Industry, the Economy and the Environment, Human Behaviour and Development, and Society and Politics) responsible for initiating research and acting as executive bodies with their respective areas.

The ESRC does not operate institutes, but funds fifteen centres in universities with 50 per cent of its budget. These are supported for five years in the first instance and support may be renewed for one or two additional five-year periods. The centres have advisory committees and are subject to annual reviews. Although in the past they have had some freedom to manage their own

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affairs and take responsibility for the details of their programs, they are now required to conform closely to the council's priorities and to follow the corporate plan.

The Science and Engineering Research Council (SERC) announces its commitment to peer review as a basis of project selection in its Corporate Plan:

> Peer review is at the heart of SERC's way of working, and SERC is one of the few organisations in the world to 'peer review' big and small science together.[4]

However SERC's commitment to peer review is exercised within an overall framework of priorities. This has been the case since the 1970s, when the first of several special directorates was established to foster research in a nationally important area where there is little in the way of existing, coordinated activity. SERC distinguishes between peer review, which it uses as the means of deciding whether or not to support particular proposals, and the overall scheme of priorities which it nominates in its corporate plan. In all, 60 per cent of funding flows to priority areas.

The other major device to focus research is the program grant, typically of £75,000 per year for four years, with evaluation by the appropriate sub-committee after two years.

Thus, the general approach to basic research selection in the UK can be summarised by three statements:

- peer review, by committees of experts chosen by Government appointed Boards remains the predominant method of selection of projects and investigators;
- there is an increasing degree of priority-setting, the priorities emerging from interaction between the same peer review committees and the various advisory bodies, through non-public processes;
- there is a strong move to concentrating research resources by provision of larger and longer grants to Programs and Centres; one implication is the establishment of procedures to review performance during the life of the grant, but the same peer review process will apparently be used.

FEDERAL REPUBLIC OF GERMANY

The most striking feature of German science policy is the limited influence of governments, and the very high level of autonomy of research-performing and promoting institutions. The freedom of research is expressly established in the Federal German constitution. In this context, and that of a generous and growing budget for basic research, and a high success rate (80 per cent), it is apparent that there is little expressed need for, and indeed a strong hostility to, notions of directed research or priority-setting.

Funding for basic research is provided jointly by the Federal and State (Laender) Governments. The Deutsche Forschungsgemeinschaft (DFG - German Research Society) is the central self-administering basic research support organisation in the FRG. It receives its funds from the Federal and State Governments, and as the primary source of 'Drittmittel' - the additional funds

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4 Science and Engineering Research Council, Corporate Plan 1989, (Swindon, 1989), p. 21.

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for research, it exerts a significant influence on the profile of basic research. An outline is provided in Figure 2.

Basic research is performed in three different sets of institutions - the 50 universities, the 60 institutes of the Max-Planck-Gesellschaft (MPG) and the 13 National Research Centres. Given the culture of autonomy noted above, decision-making about basic research selection is largely made by the DFG, or within the research performing institutions.

The DFG has a function comparable with that of the NSF in the US, but it is not a government organisation nor is it subject to government directives. It is an independent scientific society, the membership of which includes the universities, other research institutions such as the Max Planck Society and seven of the National Research Centres, and prominent scientific associations. The President and Senate are elected, as are the approximately 400 expert consultants who hold office for three years to provide the function of peer review.

As the major source of competitive funds, DFG is described as determining the profile of German academic research. However the emphasis on bottom-up approaches, and the high success rate suggest this influence may be largely a mediating one. A large part (40 per cent) of funds are distributed in response to project proposals.

A second funding mechanism supports about 110 'priority programs' intended to promote inter-institutional cooperation in a given area for up to 10 years. Identification of topics is essentially bottom-up, and following discussions, the researchers responsible are invited to submit a formal proposal. Decisions by the DFG Senate are based largely on scientific merit.

The third mechanism supports 157 priority research areas in single institutions for up to 15 years. Priorities are established by a similar bottom-up led approach, with selection occurring through the peer review process.

The resistance to direction of research is reflected in the comment:

> DFG officials are determined that targeted funds should not exceed 10 per cent of overall expenditure since this might give rise to renewed alarm about academic autonomy and flexibility.[5]

The functions of the MPG are to undertake research in areas of particular importance, or in newly emerging areas, or where a concentration of effort is required. Its legal status is that of a private non-profit organisation despite most of its finance coming from Government. Proposals are received each year and undergo an extensive evaluation process. Judgements are made by the MPG Senate on scientific merit, fruitfulness, appropriateness to the MPG (as opposed to the universities), and availability of an outstanding scientist to fill the position of leader. Once established, an institute is subject to review every two years by a visiting committee and every seven years by a prestigious panel of overseas experts.

The National Research Centres were established essentially as Big Science institutes in fields such as nuclear, aviation and space research where a large concentration of very expensive infrastructure was necessary. Some of these Centres are facing the challenge of missions completed or no longer relevant and are seeking new orientations, but while this is an extensive process, it does not appear to include any elements relevant to basic research selection.

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5 Ben R. Martin and John Irvine, Research Foresight, (London, Pinter, 1989), p. 80.

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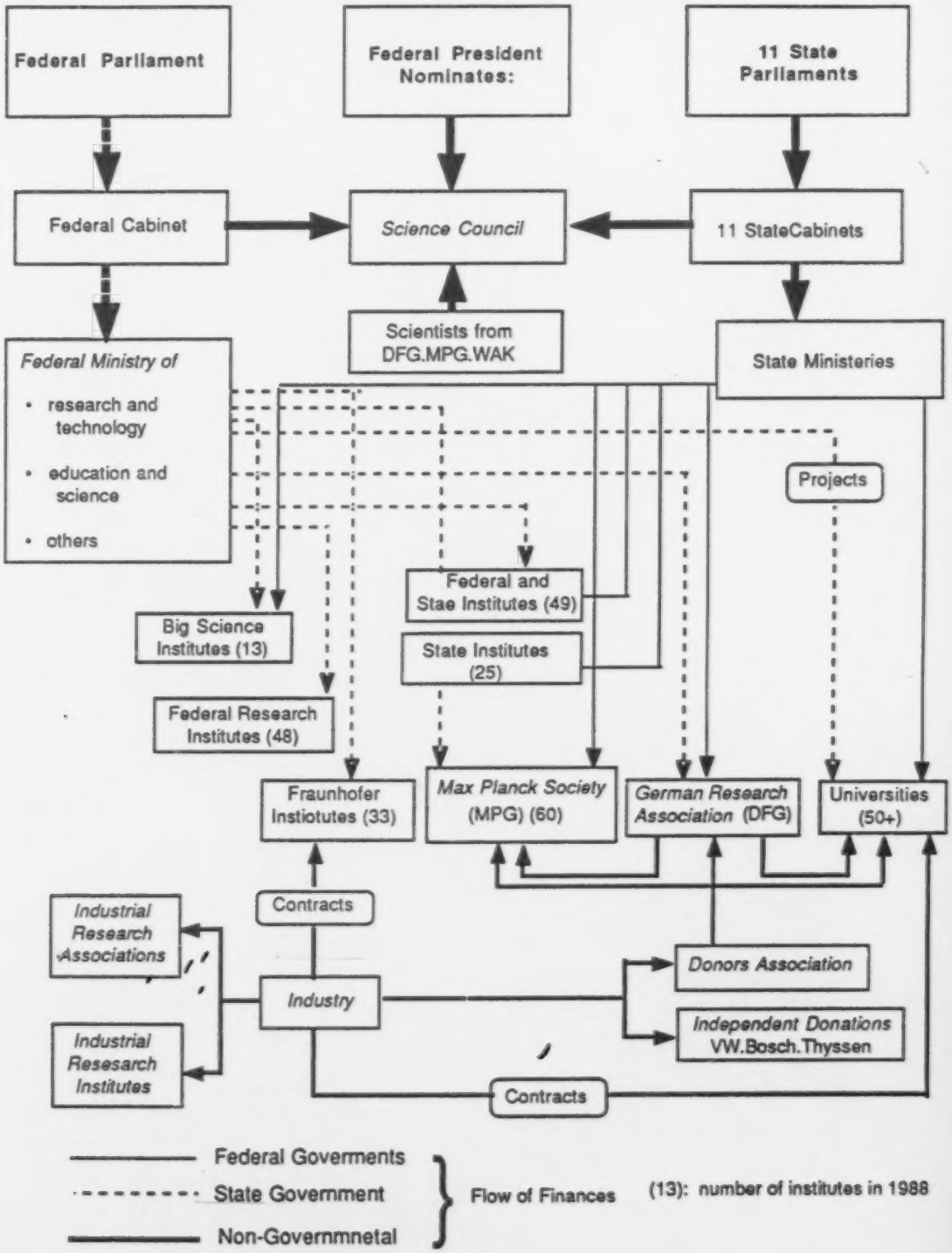
Figure 2 Organisation of Research and More Important Flow Lines for Funding in the Federal Republic of Germany



Source: Bundesminister fur Forschung and Technologie, 1988.

We conclude that basic research selection in the FRG rests essentially on a bottom-up proposal pressure and peer review. Priority-setting is not common for basic research except where used to achieve concentrations of research effort through cooperative teams or centres.

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FRANCE

The French approach to decision-making for basic research, as for all areas of the economy and society, rests on a traditional commitment to planning. Five-year National Plans have been the foundation of decision-making. In the area of research the strong emphasis is on economic goals, and priority is given to industrial research. An outline of the French R&D system is provided in Figure 3.

The Ministry of Research and Technology has responsibility for implementation of government policies in the field of science and technology, and to the determination of priorities for research, with the advice of the Research and Technology Council. The performance of basic research occurs within the universities, which receive core funding from the Ministry of National Education and the Centre National de la Recherche Scientifique (CNRS) research agency. The French System relies on block grants to the laboratories and research groups rather than specific project grants to individual researchers.

One of the major programs to direct the research being performed in research agencies more effectively towards national needs, and to concentrate research in fields identified as strategically important have been the **programmes mobilisateurs**, which are directed to particular generic technologies.

The **CNRS**, the governing Council of which is partly elected, finances the entire range of basic research from the physical sciences to the humanities. Annual strategic plans are prepared which rely as much on the identification of leading research individuals and groups, as on promising areas of research. In addition they have conducted a range of prospective studies, described in detail in Martin and Irvine[6], which feed into the planning process.

The French Government has recently mounted a major initiative to promote the strategic application of foresight and evaluation to the national research system. A 'National Research Evaluation Committee' (CNER) has recently been established. This follows the experience of the National Evaluation Committee of the Universities (CNE/EPSCP), founded in 1985, which has assessed the research of 25 universities on a voluntary basis. The CNER was established in response to the Government's decision to institute the systematic periodical assessment of all research-performing institutions.

The CNER is responsible for the evaluation of the organisation and results obtained by the implementation of a national technological research and development policy. To achieve this goal, the committee ensures, upon its own initiative or upon request of the Minister in charge of Research, the periodic assessment of institutes programs and incentives of all kinds financed from the civilian technological R&D budget.

The central focus of the CNER is that its assessments 'must be able to be used to evaluate whether of not scientific and technical orientations decided upon and choices made are legitimate, whether resources committed to research programs can be justified, if joint actions undertaken (especially with private companies) have worthwhile results". The CNER is also responsible for the analysis of 'the economic, industrial, scientific and cultural implications of the scientific and technical results expected' notably 'on a European and international scale'.

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6 Ben R. Martin and John Irvine, (1989), op cit., pp. 47-50.

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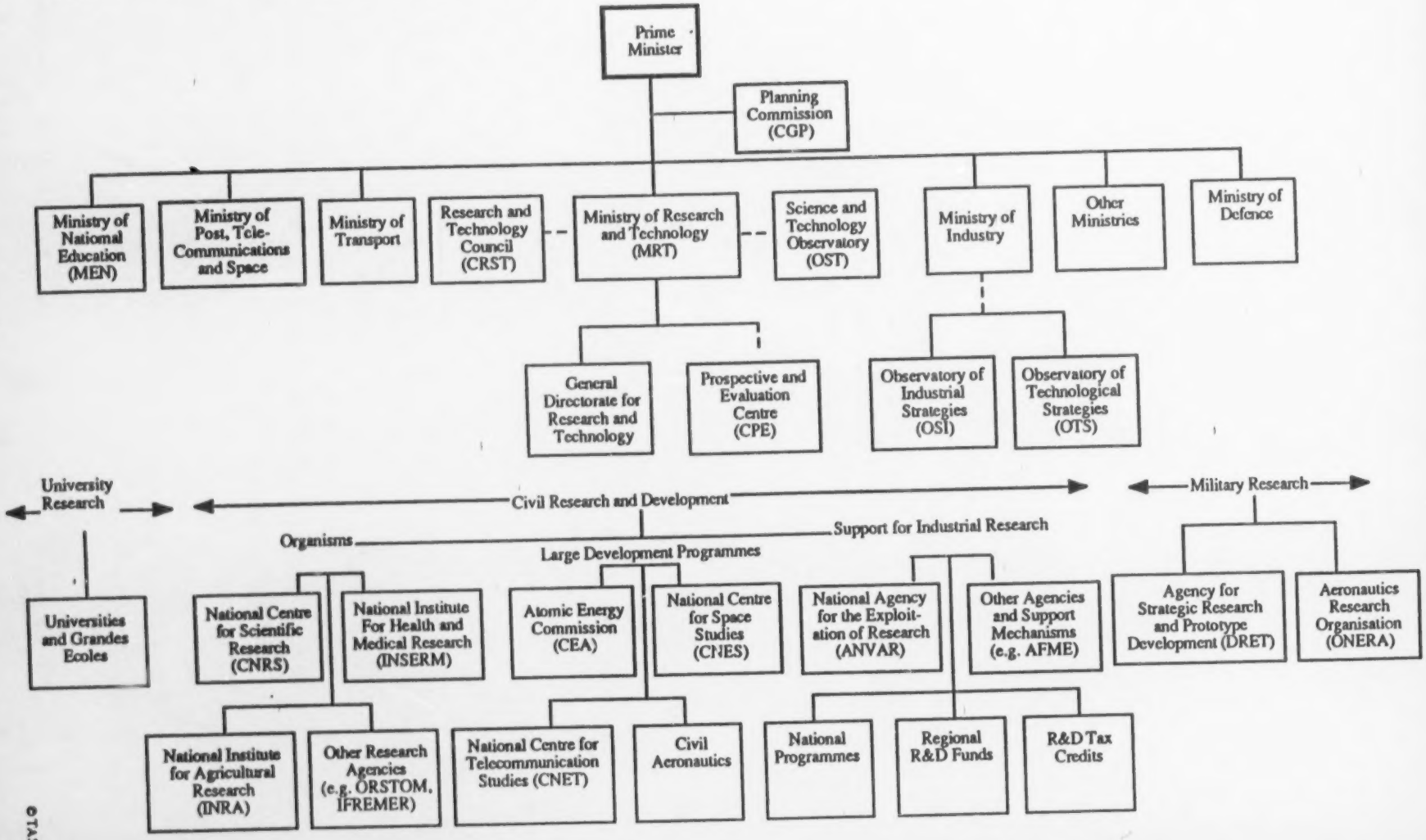
Figure 3 Outline of the French R&D System


Prime Minister
Planning Commission (CGP)
Ministry of National Education (MEN)
Ministry of Post, Tele-Communications and Space
Ministry of Transport
Research and Technology Council (CRST)
Ministry of Research and Technology (MRT)
Science and Technology Observatory (OST)
Ministry of Industry
Other Ministries
Ministry of Defence
General Directorate for Research and Technology
Prospective and Evaluation Centre (CPE)
Observatory of Industrial Strategies (OSI)
Observatory of Technological Strategies (OTS)
University Research
Civil Research and Development
Military Research
Organisms
Support for Industrial Research
Large Development Programmes
Universities and Grandes Ecoles
National Centre for Scientific Research (CNRS)
National Institute For Health and Medical Research (INSERM)
Atomic Energy Commission (CEA)
National Centre for Space Studies (CNES)
National Agency for the Exploit-ation of Research (ANVAR)
Other Agencies and Support Mechanisms (e.g. AFME)
Agency for Strategic Research and Prototype Development (DRET)
Aeronautics Research Organisation (ONERA)
National Institute for Agricultural Research (INRA)
Other Research Agencies (e.g. ORSTOM, IFREMER)
National Centre for Telecommunication Studies (CNET)
Civil Aeronautics
National Programmes
Regional R&D Funds
R&D Tax Credits

Source: Constructed from Government science-policy documents

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Since there are no objective yardsticks for measuring success, the strength (and usefulness) of these assessments depends on their credibility.

As far as this problem is concerned, a certain number of conclusions have been reached from the experience of countries in Western Europe.

- assessments must be made by a group of people (panel);
- these people must be independent and this independence can be evaluated by means of the following criteria: first, the degree of 'outsideness' from the operator to be assessed and second, the fact that this assessment be considered a job and therefore paid. This practice, frequent abroad, has always been problematic in France;
- because no research institute is organized in the same fashion, each assessment must define its own approach and determine its own methods of investigation;
- assessing socio-economic impact as well as managerial performance often implies the necessary recourse to outside consultants at a cost which must be taken into account.

The 'strength' of these assessments usually depends on the choice of the assessors and their approaches. Four points characterize the CNER's:

- the committee does not itself carry out assessments; it designates 'panels' and defines their terms of reference and work methods. In such a way, the CNER guarantees the independence of experts involved and the reliability of results obtained;
- it is totally independent form the point of view of the organization of its own work;
- it represents a moral authority symbolized by the designation of its members 'by decree promulgated by the Council of Ministers', its composition and its procedure chosen by them. Out of the ten members of the CNER, there are four representatives of the scientific and technical community, chosen from two lists presented respectively by the Superior Council of Research and Technology and the Academy of Science e, four famous personalities are chosen because of their competence in the economic, social, cultural, scientific and technical fields, one member is from the Council of State and one member from the Office of accounts (Cour des Comptes);
- the Ministry of Research and Technology supplies the secretarial staff and the financing required by the CNER, ie, ten salaried positions for its secretarial staff and 10 MF/yr to finance operating costs and the dozen assessments per year that the committee should carry out to cover all the national operators within a period of six years (mandated term of its members)."[7]

However, the conclusion must be that while there is a strong emphasis on the planning and direction of research towards technological objectives, basic research directions in the universities are determined largely on the grounds of scientific excellence, and within CNRS by the scientific departments putting forward proposals which are judged internally on grounds of merit and relationships to priority areas.

JAPAN

The dense population, a deep commitment to the values of the group and the spiritual principles of Confucianism has produced a culture which emphasises the values of harmony, respect, and decision-making by consensus, even if the process needs to be very extended. These values permeate the decision-making structures and procedures with respect to science.

The organisation of the national science administration is shown in Figure 4.

Within the government, the Prime Minister's Office and its key policy body, the Council for Science and Technology (CST), exercises the highest level of control over the direction of scientific and technical research. The Science and Technology Agency is responsible for the overall coordination of science policy among the different ministries and agencies. It is also responsible for 'big science' and has attached research institutes to fulfil this function.

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7 'The National Research Evaluation Committee (CNER) - Its Role in the French Research Evaluation Network', **Research Evaluation Newsletter**, 90.1, 1990

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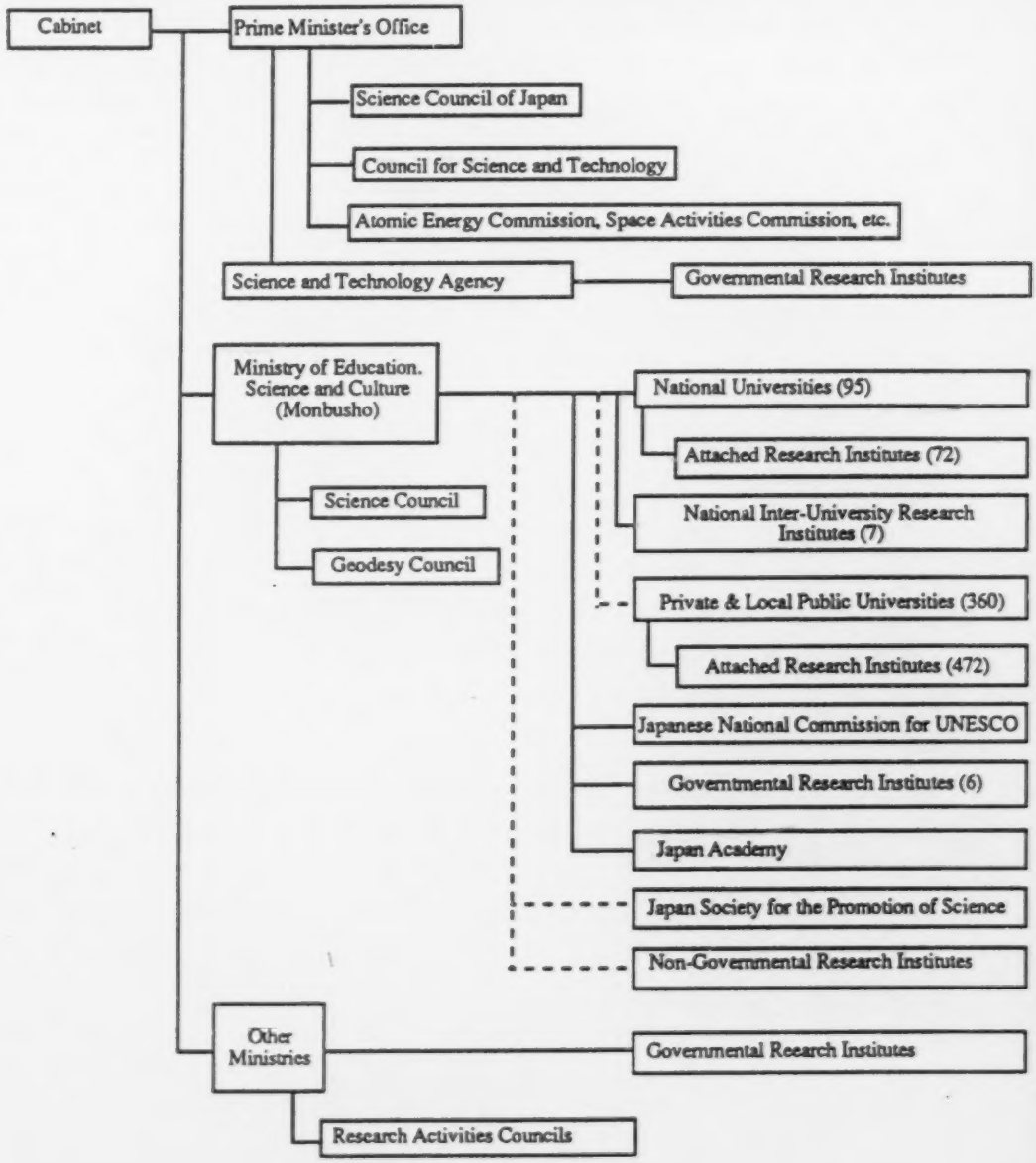
Figure 4 Organization of National Science Administration



The Ministry of Education, Science and Culture (Monbusho) is responsible for the promotion of research across all fields, and for the national university system. In formulating policies, Monbusho consults its Science Council, consisting of twenty-seven eminent scholars appointed by the Minister.

The Science Council of Japan is a democratic body established by law as the representative body of Japanese scientists. It is financed out of the national budget and members are put forward by the academic societies, but approved by the Prime Minister's Office. It has the right to make recommendations directly to the government on the ways and means to promote science and technology. Among its major successes was the establishment of nine inter-university research centres. However in recent years its influence has waned in favour of the CST.

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The role of the CST in integrating and coordinating research has been considerably strengthened through the establishment of a Science and Technology Promotion Coordination Fund, which is used in part to support basic research in special priority fields designated by the Council.

Research in the national universities is provided for almost entirely by Monshubo through the provision of three types of fund. First, general research funds are allocated to each koza, or to each division of a department of a university faculty. Funds are decided by a standard formula based essentially on the number of researchers, the nature of the research (experimental, non-experimental or clinical) and whether or not the koza or division is in charge of graduate courses.

Second, special research funds are allocated to national universities for the provision, construction and maintenance of facilities and equipment necessary for specific research programs. Requests for such funds are incorporated into Monbusho's own budget request to the Ministry of Finance. Third, grants-in-aid are awarded to researchers or groups of researchers whose applications are approved by MESC's Science Council.

The Committee for Grants-in-Aid for Scientific Research contains numerous advisory committees dealing with requests for grants from the various fields of science. More than 800 people, largely university professors and a few emeritus professors appointed by MESC, serve on these committees and award eleven different categories of research grant worth, in total, around Y39,500 million in 1983. The major categories of grants are outlined in Table 2.

Table 2 Research Grant Category

Special Promoted Research 2.3 billion yen	Internationally renowned research which is likely to produce outstanding results
Special Long-term Research 2.9 billion yen	Long-term research in the field of especially strong scientific and social needs , e.g. cancer research and fusion research
Priority Areas Research, Special Project Research 10.7 billion yen	Fixed-term targeted research in the field of strong scientific and social needs such as materials science (solid state physics, chemical materials, new materials), information electronics (information science, electronics), life science (bio-science, cancer, neuroscience), earth, space science (environmental Science, geo-physics, space) energy science (new energy, energy saving), humanities and social science (for one area 50 - 600 million yen, period 3-6 yrs); all told there are 60 priority areas
Cooperative Research 2.7 billion yen	Research carried out by researchers belonging to different institutions
General Scientific Research 15.7 billion yen	Research carried out by a researcher or group of researchers belonging to the same institute. The most popular category of the program and sub-divided into three categories according to the amount of funds required. Category A 10 - 50 million yen " B 3 -10 " " C less than 3 " "
Developmental Scientific Research 4.1 billion yen	Applied research whose outcome is likely to be put into practical use
Encouragement of Young Scientists 4.7 billion yen	Research by a young researcher (37 yrs or less) of an institute (category A), research by a school teacher or a researcher of the town (category B)
Overseas Scientific Research 2.3 billion yen	Survey or research conducted abroad
Scientific Research Promotion 2.3 billion yen	Support for urgent and important research
Publication of Scientific Research Results 1.2 billion yen	Support to diffuse the research results and information materials of high scientific value

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From this fiscal year (FY90 - began 1 April 1990) Monbusho has a new program in which, rather than calling for applications, the Science Council has chosen research fields for priority funding. Under this new program, the Science Council during the preceding fiscal year selects two fields for special research funding; it then selects a project leader for each field. The leader draws up a research proposal (5 year program), including a list of participant researchers (almost all from within the Monbusho umbrella, i.e. universities and Monbusho research institutes, although that is not a necessary element).

The draft program is considered by the Science Council, which can seek amendments if necessary, and the grant is eventually made for the full five years, starting with the following fiscal year.

The two projects which will begin in FY90 are 'Global Environmental Change in the Asia-Pacific' and 'Biological Study of the Brain'.

The decision on which fields to support is taken by the Science Council. In theory the Council discusses possible fields and decides on the two to be supported in a completely independent fashion.

Ex-post evaluations are applied routinely to research grant recipients. Grants are normally for periods of several years, and after the grant expires the research is evaluated by a committee of the Science Council. Sometimes this leads to a research project or team not being funded subsequently. Such evaluations, however, are not likely to lead to decisions that entire fields of research are over- or under-funded.

Thus it may be concluded that the essential process of basic research selection is through the time-honoured mechanism of a committee of wise men. Priorities are established by this process, involving varying degrees of interaction with an influence of academic researchers on the one hand and government officials on the other. A variety of techniques (see Martin and Irvine, op. cit) are used to assist in establishing these priorities, but the selection methods have undergone little change.

NETHERLANDS

The Dutch have taken the lead in the formulation of Science Policy in Europe, and have carried the implementation much further than in many other countries. Their history and political system appears to combine a considerable degree of essentially conservative stability with a capacity to engage in quite radical experimentation and change. The major emphasis of science and technology policy has been on a more effective planning and linking of strategic and applied research to national economic and social needs. The Minister for Education and Science has recently produced a discussion document 'Towards a Science Policy for the Nineties'. As a result the Government has now decided to place science at the top of the Dutch political agenda. The three major objectives delineated for the 1990s have been:

- establishment of a more effective scientific basis for key societal functions;
- achievement of an important role of research in the process of internationalisation;

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- a well-balanced development and application of science and technology to economic, social and cultural needs.

The independent Science Policy Council of the Netherlands (RAWB) is the central advisory body on science policy; it has had a significant influence on priority setting and resource allocation through the preparation of reports on future needs and opportunities in particular fields. It is shortly to be transformed into an Advisory Council for Science and Technology Policy (AWT).

Basic research is performed essentially in the universities which are funded by the Ministry of Education and Science (which administers the 54 per cent of the Government R&D budget) and in the institutes established by the Netherlands Organisation for Scientific Research (NWO). The latter also funds some basic research in universities.

University research remains the major area of publicly funded science and technology. It has however, only recently become a central issue in the context of national science policy-making.

Before the second half of the 1970s university research was largely considered in relation to educational policies, with particular emphasis placed upon the close relationship between academic research and university teaching. Gradually there has been a shift in approach developed in the last decade or so, and academic research objectives are being increasingly related to external economic and social requirements.

The scope for effective planning and steering of the direction of university research in the context of science policy has been constrained in the past by the funding structures for university R&D. Prior policy was largely to leave academic research to itself with funding through a three tiered process:

Tier 1 (70-75 per cent) general funds provided to universities under a policy that treated all universities the same and left the allocation of these funds up to each of them.

Tier 2 (15 per cent) specific research grants based upon peer review from the Netherlands Organisation for Pure Research.

Tier 3 (10-15 per cent) funds for specific priority research areas (such as contract research, partly funded by industry).

Late in 1979 the Government published a new policy on university research funding. The policy aims at improving the visibility and accountability of research at universities and also to improving the efficiency and quality of university research.

Universities now receive about 45 per cent of government R&D funds with less in the form of general funds (Tier 1 funding), about the same for research grants (Tier 2 funding), and an increasing amount for Tier 3 contracts, many of them in the framework of specific government priority research areas (e.g. biotechnology, electronics, informatics). Lesser priority is now given to medical sciences and public works.

A major new element in the planned university research policy is the introduction of an additional funding channel: the 'conditional funding' of research activities. This involves distributing

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funds (a proportion of Tier 1 funds) among university research groups in the context of multi-year guidelines and development plans. All universities are invited to submit research programs of any significant scale to the Ministry for Education and Science. The entire list is then assessed by a group of experts and successful projects are guaranteed support for five years. The guidelines are designed to provide a greater scope for planning and coordination of the total university research effort over different disciplines and academic establishments. This process takes particular account of nationally agreed strategies in the distribution of research responsibilities, as well as of research programs seen to be of particular social or scientific significance. It is the government's aim to allocate an increasing share of the Tier 1 funds for university research to the conditional financing scheme.

A further goal of government policy has been the need to reinforce the move to conditional financing by channelling a greater proportion of university funding through the 'second flow'. In addition to extending the use of peer-review in the academic system, this would introduce a measure of external influence in setting broad priorities for university research in line with longer-term national needs. Competitive research council grants have doubled in real terms during the decade and account for 16 per cent of academic R&D funding by 1990. Furthermore, greater emphasis on socio-economic relevance would be achieved by expanding the opportunities for universities to obtain 'third flow' finance for commissioned work from public-sector agencies.

A feature of policy in the last few years has been the move gradually to transfer responsibility for basic research from government departments to the universities, or to institutes operated by NWO. This represents one element in a developing strategy to reshape the existing national R&D system, which is widely seen as lacking the degree of integration and coherence that is needed if the country is to maintain an internationally competitive effort in key areas over the next decade.

A significant role is thus played by NWO which funds some 15 per cent of basic research in the country. This is a statutory body responsible to the Minister for Education and Science with funds provided through the Ministry. Its budget in 1989 was mill Dfl 323. The objectives of the organisation are the stimulation and coordination of pure and applied research in the Netherlands in all fields of learning: natural sciences, medical sciences, biological sciences, social sciences and humanities. The organisation has autonomy in all matters concerning scientific research.

NWO promotes scientific research by providing financial assistance to scientific projects and programs and by awarding various short-term and long-term travel grants through a program of fellowships. The second objective of the organisation, the coordination of research, is achieved by bringing together qualified scientists working on related projects. These researchers are mainly employed by the universities, for so-called 'national working communities' where plans for future research projects are developed, programs evaluated and where research priorities are set.

The 29 NWO-foundations, each consisting of a number of working communities, are responsible for the development of research programs within the framework of the research-policy set out by the respective Council.

The NWO, like the German DFG, has a peer review based selection system, in which the peers are elected by the wider scientific community.

A particular feature of the Netherlands is the extent to which the universities themselves have moved towards the application of methods other than that of peer review to the allocation of funds to

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research. There has been an extensive development and application of bibliometric measures (publications and citations in particular) which are used, along with peer review, in determining allocations of university research funds to departments. A detailed account is available in Moed[8].

The Dutch government, bureaucracy, and universities have been particularly active over the past decade in reshaping their science and technology policy decision-making procedures and capabilities. While most of this effort has been directed to technology development, there has been some attention also to methods of project selection for basic research. These have relied on an increase in the proportion of funds allocated on an externally (i.e. nationally) competitive basis and the allocation of an increasing proportion of funds to priority areas. The priorities are determined by traditional committee methods where scientific and government interests meet and negotiate from their own perspectives. Once priorities are set, traditional mechanisms of calling for proposals, followed by judgement by a committee of peers, aided by the reports of referees (other peers), are followed. The only new variations are in methods of selection of the peers to make selection decisions.

SWEDEN

There is a long tradition of extensive government involvement in decision-making in a wide range of areas in Sweden, backed up by an extensive process of consensus formation. R&D has been strongly directed, particularly through the central establishment of priorities and funding levels every triennium in a Government Research Policy Bill.[9]

These priorities are developed through an interactive process between funding agencies, Departments with responsibility for R&D and a group in the Cabinet office with overall responsibility vested in the latter. There is a strong 'bottom-up' element in the decision making process which is set against the background of the presentation of a Bill on Research to the Swedish Parliament at three-yearly intervals. The fact that this bill is programmed into the legislative process allows all the players to develop their initiatives in the period leading up to the tabling of the Bill. Thus the research institutes associated with Ministries carry out their own background studies, usually through their research agencies, e.g. the National Board for Technical Development (STU) in the Ministry of Industry has a major input on longer term strategic research and generic technologies as well as identification of emerging interdisciplinary areas. The Ministry also uses the extensive monitoring of foreign R&D provided by the Swedish Foundation for Technical Attaches which has offices in all the main industrialised nations, including three in the USA. The Royal Swedish Academy of Engineering Sciences (IVA) organises symposia bringing together researchers and industry to discuss emerging developments in science and engineering and produces influential reports to Government. In the case of basic science, the four Research Councils of the Ministry of Education and Cultural Affairs provide inputs based on the perceptions of the research community of emerging new areas of science and of the needs for infrastructure support. The Cabinet Office itself funds twenty Professors to travel around the world and provide a further input on world developments in science and technology, and particularly on Sweden's role in European research and development.

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8 H. F. Moed and A.F.J. van Raan, "Indicators of Research Performance: Applications in University Research Policy" in van Raan, A.F.J. Handbook of Quantitative Studies of Science and Technology, (Amsterdam, North Holland, 1988).

9 George Ferne, Science and Technology in Scandinavia, (London, Longman 1989).

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The process of consultation and debate ensures that all interested parties have an opportunity to make their views known and that the community in general is committed to the areas and issues identified in the Research Bill. A new Bill is due for February 1990 and priority areas for this will be:

- strengthened basic research in universities;
- increased research in five identified target areas - environmental areas, marine environment, public health, industrial safety, and cultural research.

Basic research is conducted almost entirely within the universities - there is virtually no government research capacity. Infrastructural support is provided by the Ministry of Education and Cultural Affairs on the advice of the National Board of University and Colleges (UHA). Project-based finance for basic research comes largely from two research councils - the Natural Science Research Council (NFR) and the Council for Planning and Coordination of Research (FRN), which initiates interdisciplinary research for societal needs.

The UHA advises the Minister on the distribution of core funding to the university sector. Advice is formulated largely in accord with project student demand and performance. One area of selection which impinges on basic research is with regard to the establishment of new chairs and the renewal of existing ones.

In basic research, which is largely carried out within the university sector and is roughly a quarter of Swedish R&D, the four research councils play a major role in determining research areas and resource allocation. The four councils are: The Medical Research Council, Natural Science Research Council, Council for Research in the Humanities and Social Sciences, and Council for Planning and Co-ordination of Research.

The National Science Research Council (NFR) which is the largest of the four councils, has a budget of about 400 mill SKr and supports research in a wide range of physical, biological and environmental fields against a mission of maintaining a strong fundamental effort in the universities. Overall policy is set by the NFR Council which consists of a Chairman and three members nominated by Government and seven chosen by an electoral college nominated by the academic community. The Council is supported by a secretariat of roughly 35 people.

Policy is largely set by responses to applications from researchers, i.e. bottom-up approach, through a number of program committees. These consist of 1-2 Council members plus 16-20 scientists. It has been suggested that 'the dominance of academic scientists in NFR means that the organization tends to operate in a responsive mode, only initiating new lines of research after significant proposal pressure".[10] Because of the relatively small scientific community, foreign scientists are used for evaluation of activity in particular fields. These inputs are seen as valuable in ensuring international quality of research and in indicating new directions of research. This leads to some degree of top-down approach through the setting-up of ad hoc interdisciplinary committees for particular topics, e.g. high temperature superconductors.

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10 Martin & Irvine, op cit., p. 280.

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Since some 40 per cent of funds is now being directed into international links through projects or access to large facilities, there is a strong element of top-down planning to ensure that Sweden gets maximum value from its funding.

Recently, the NFR has adopted a different approach to support research in the field of materials science. Consortia of university departments have been invited to propose interdisciplinary multi-year programs. The proposals are evaluated on the basis of scientific excellence but also take account of organisational and managerial aspects.

Project evaluation is conducted on a regular basis for projects of multi-year duration. Levels of performance and output are assessed by the NFR to determine the basis for continuation of funding.

The **FRN** addresses a wide range of societal concerns, ranging from ageing to regional development. Hence its Board's members are drawn from a wide range of sectors and groups. Its decision-making processes have been described as follows:

> Once an area has been identified as a candidate for support, an *ad hoc* committee is usually established to identify research needs and opportunities and to propose a programme. Committees are typically cross-disciplinary and include both research 'producers' and 'consumers'. They rely principally on internal discussion coupled with consultation of researchers and other interested parties.[11]

Thus while strong direction setting characterises Swedish strategic research, funded largely by the National Board for Technical Development (STU), there has been relatively little development of new project selection techniques for basic research. The three-yearly Research Bill provides a strong framework which undoubtedly influences the distribution of all funds for research, but the effect on basic research is indirect. Once priorities are set, selection rests on peer review, by reference and committee. One special feature is the systematic use of international referees.

CANADA

Canadian science policy has been marked over the past decade by a high level of debate, conflict and change. The major pressure for this change has been the heavy reliance of the Canadian economy on its resource-based industries and the recognition that such economies are becoming increasingly vulnerable and non-competitive. Canada has a considerable reputation for scientific excellence and long-established central government laboratories.

Canada is a federal system, with the special requirements for coordination that implies. Even non-federal countries such as France, Italy and Spain, have strong regional interests which need to be accounted for. A key factor in planning is not so much whether there are different regions, provinces or states, but where the funding for certain activities comes from. In the case of Canada, the higher education sector is almost entirely funded through the provincial governments, while other research is funded nationally. There is a quite different perspective on planning for these different sectors.

There is a range of advisory and decision-making bodies in the Canadian science and technology system, as shown in Figure 5. The National Advisory Board on Science and Technology

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11 Martin & Irvine, op cit., p. 282.

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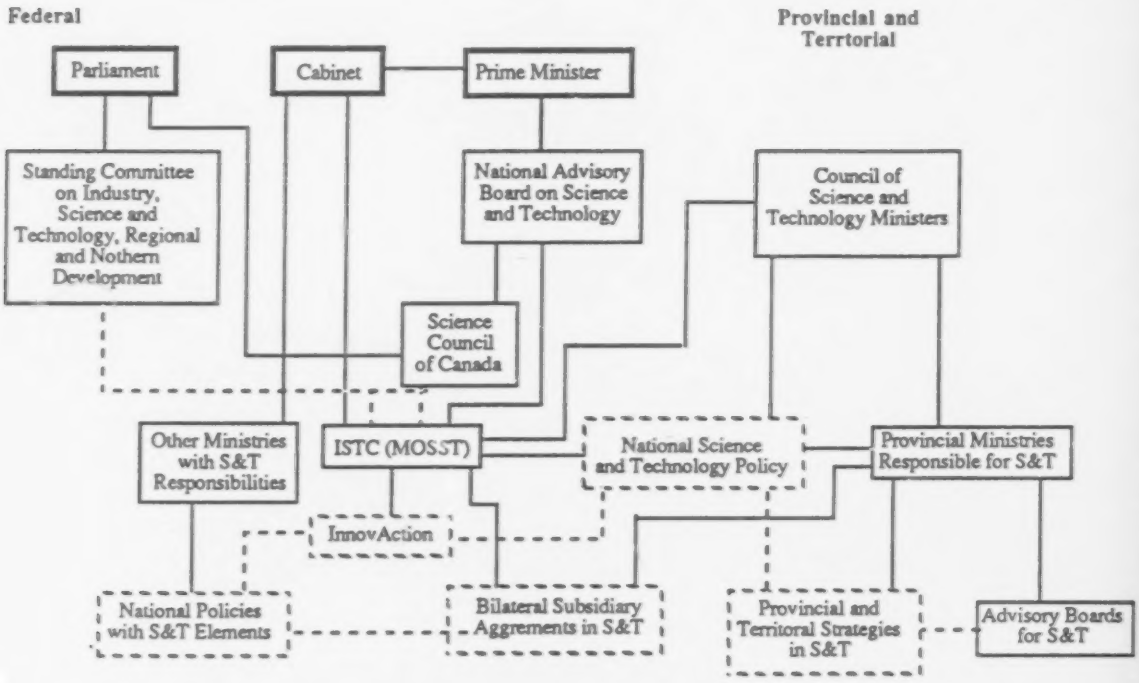
advises the Prime Minister on overall guidelines for federal R&D. Responsibility for research and industry have been integrated in the one portfolio - Industry, Science and Technology Canada (ISTC); the Minister is advised by the independent Science Council of Canada.

Figure 5 Key Elements within Canada's National Science and Technology Policy Apparatus


Federal
Provincial and Terrtorial
Parliament
Cabinet
Prime Minister
Standing Committee on Industry, Science and Technology, Regional and Nothern Development
National Advisory Board on Science and Technology
Council of Science and Technology Ministers
Science Council of Canada
Other Ministries with S&T Responsibilities
ISTC (MOSST)
National Science and Technology Policy
Provincial Ministries Responsible for S&T
InnovAction
National Policies with S&T Elements
Bilateral Subsidiary Aggrements in S&T
Provincial and Territoral Strategies in S&T
Advisory Boards for S&T

The Council is a long-established organisation which provides independent advice on science and technology, initiating and publishing its own studies as well as undertaking commissioned work. The Science Council has been a long-time advocate of systematic research priority setting and has undertaken a number of reviews of national needs and opportunities in research and development.

One responsibility of ISTC is the Decision Framework for Science and Technology, which requires departments and agencies responsible for R&D (including those funding basic research) to prepare annual lists of priorities. These are compiled by the Minister into an Overview which identifies gaps, duplications and key issues and which is used in government determination of strategic directions for R&D.

University funding which supports the great majority of basic research is provided by a traditional dual support system. Core funding is provided by provincial governments (via the Federal Government) and supplemented by project-based grants from the Natural Sciences and Engineering Research Council (NSERC), the Social Sciences and Humanities Research Council (SSHRC) and the Medical Research Council (MRC).

The major initiative designed to increase the concentration and coherence of research in the universities has been carried out under the Canadian Strategy for Science and Technology which was called InnovAction. Under this scheme CA$240M was allocated over five years for the establishment of a network of national Centres of Excellence. Table 3 shows the 14 Centres

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established. A particular feature of these Centres is their emphasis on network formation. Each involves on average ten institutions from the university, government and industry sectors. Selection relies on the assessment by an ICST committee of excellence with the assistance of national and international referee's reports, as well as contribution to industrial competitiveness.

Table 3 Canadian Federal Centres of Excellence

Bacterial Diseases
Biotechnology for Insect Pest Management
Space Research
Molecular and Interfacial Dynamics
Genetic Basis of Human Diseases
High Performance Concrete
Robotics and Intelligent Systems
Telecommunications
Molecular Devices, Circuits and Systems for Ultra Large Scale Integration
Ocean Production Enhancement
Protein Engineering
Respiratory Health
High-Value Papers from Mechanical Wood-Pulp
Neural Regeneration and Functional Recovery

NSERC has the prime responsibility for funding academic science and engineering research. Like other federal agencies, it is required to develop a corporate plan which is based on the views of the appointed Council members, in the main scientists and engineers, and the secretariat. This plan is used more to defend the budget of the Council than to establish priorities.

Over 60 per cent of NSERC's budget is allocated to the research base - project grants to individuals and for collaborative research, selected by a peer review committee-based process. There has been a continuing debate in NSERC over the past decade on the extent to which individual scientists should remain free to set their own research directions and priorities.

However, on the basis of the provision by the Federal Government of extra funding, a Strategic Grants Program was established which directs 17 per cent of the Council budget to research more closely oriented to societal needs. The Science Council was commissioned in 1987 to establish a systematic basis for program selection by identifying a list of thirty broad themes for research in the three national priority areas (information technology, biotechnology and advanced materials) and in other promising strategic fields. The major mechanisms used relied on committees of researchers and users, workshops and informal consultation.

The SSHRC finances academic research in the social sciences and humanities through discipline-based project grants and strategic research programs. As with NSERC, there has been strong opposition to targeting of research, but with extra funds, the Council now commits 15 per cent of its budget in this way. Selection of priorities was based on biennial seminars aided by commissioned reviews of opportunities in specific fields. However, Martin and Irvine have noted, 'most academics still have a clear preference for undirected research'.[12]

Thus while there has been a strong push towards linking research more effectively to national needs, this has been stoutly resisted in the case of basic research. The overall framework of planning thus far impinges only fairly indirectly, and the extent of targeting remains a small proportion of the basic research funded. The procedures to establish priorities have involved elaborate consultation, but once established, selection is by traditional peer-based methods.

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12 Martin and Irvine, op cit., p. 258.

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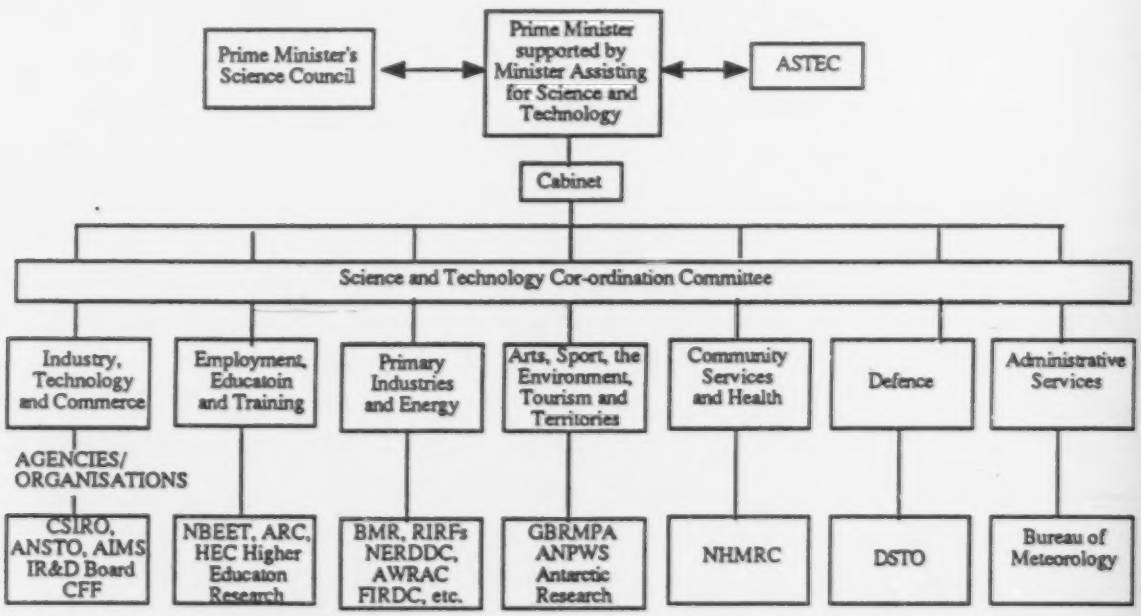
AUSTRALIA

Australia is in many respects similar to Canada, with its federal structure and its drive to broaden and deepen the technological intensity of its predominantly agricultural and minerals-reliant economic base. There is also a long tradition of commitment to internationally excellent research, with a particularly strong government research capability in the CSIRO.

The structure of the science and technology system is shown in Figure 6. In recent years Australia has developed a sectoral model of science policy, with major R&D funding and performing responsibilities spread across a number of major departments. To overcome problems of fragmentation a Coordination Committee of Science and Technology, made up of senior officials from the Departments, has been appointed. In addition, the Prime Minister receives advice from his Science Council, composed of Ministers, industrialists and a minority of scientists, and the Australian Science and Technology Council (ASTEC), composed of appointed academics and industrialists.

Figure 6 Commonwealth Organisation of Science and Technology in Australia



Science and technology is an essential part of a number of Commonwealth Government portfolios

With nearly 70 per cent of research in the public sector, there has been a considerable emphasis on restructuring, with CSIRO (like the Canadian National Research Council) being reorganised to give greater priority to strategic research directed to medium- and long-term industrial needs. The universities, which are established under state legislation but funded by the Federal government, are also under increasing pressure to serve national interests. Core funding is provided by the Department of Employment, Education and Training (DEET), which also administers the Australian Research Council which provides funding for basic research in all fields with the

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exception of health and medicine; this is the responsibility of the National Health and Medical Research Council (NH&MRC).

The core funding for universities at present includes a component for the support of research, though there is no direct accounting of research performance. However DEET has invested significantly in the development of institutional research profiles. This, together with the Minister's commitment that the nexus between teaching and research be weakened[13], indicates that a greater differentiation with respect to research performance, as is occurring in the UK, may well be introduced into Australia.

The majority of the ARC's funds have been distributed in the past by the well tried procedures which rely on a panel of disciplinary experts assessing proposals with the assistance of referee's reports. This selection procedure has been applied also to initiatives directed towards achieving concentration, as the Special Research Centres. These were selected for six year funding by a panel of leading researchers using a competitive proposal-based procedure, with scientific excellence as the main criterion for assessment. After three and six years the performance of these Centres was reviewed by a broad-based non-expert committee to determine future funding.

More recently, a number of broadly defined priority areas have been established through a procedure involving a call for submissions from interested parties including researchers, institutions, professional associations, government departments and industry. The Council of appointed researchers determined the general areas of priority and in 1989 allocated 12 per cent of the budget to proposals in these areas. The selection processes are otherwise unchanged. The NH&MRC has adopted a similar approach.

In February 1990, the Prime Minister announced a new scheme of Cooperative Research Centres, which will lead to an injection of A$100 million of new funds into basic research in centres, involving strong collaboration between the universities and CSIRO. Priorities have not been indicated. A special committee drawn from the Prime Minister's Science Council and other research funding and performing bodies will be charged with assessing proposals.

The Australian experience shows that the principles and practice of priority-setting has been strongly, and effectively, established for strategic and applied research. However, extension to basic research has met with a degree of resistance from researchers and universities, who have seen it as a challenge to their autonomy. Hence, priorities have been applied to basic research to only a modest extent, and the selection processes remain firmly based on peer assessment methods.

INDIA

Science and technology (S&T) in India has grown under a strong and sustained political support. Even before India became independent in 1947, the national leaders had recognised the role of S&T in national development. S&T under Nehru's vision came to be accepted as an instrument not only for industrial and economic development but also for transforming a traditional-bound society into a dynamic and progressive nation. The Constitution of India, adopted in 1950, reflects this political vision. The directive principles and the fundamental duties outlined in the constitution

13 Minister for Employment, Education and Training, Research for Australia: Higher Education's Contribution, (Canberra, Australian Government Publishing Service, 1989).

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state: 'It shall be the duty of every citizen of India to develop Scientific Temper, humanism and spirit of inquiry and reform'[14].

In line with the concept of socialism, the state continues to be a strong supporter of S&T, providing 80 per cent of funds for all research and development undertaken in the country. It also shoulders responsibility for directly guiding and planning the activities of an extensive network of S&T institutions. Though the basic orientation of national S&T policy has been, and still is, to treat science and technology as an integral part of socio-economic development, there have been several changes in the organisation and planning strategies over the years.

For example, the Industrial Policy Resolution of 1948 allowed considerable scope for introducing foreign technology into the country, but had little to say on linking the imports with indigenous S&T infrastructure. The favourable sterling balance accumulated during the war enabled a relaxed view on imports on one hand, and the Scientific Policy Resolution with emphasis on spirit of free enquiry allowed for independent growth of S&T on the other. Under this policy ethos, an extensive research infrastructure came into existence within a period of twenty years, almost undisturbed by the successes and failures on the economic front. The priorities in S&T were set by the leaders of science. Efforts at formulating policy instruments and plans to couple S&T capabilities with requirements of agriculture, industry and other economic sectors were weak.

The S&T organisational framework is shown in Figure 7. The Prime Minister has always been the minister-in-charge for science and technology. For this he has three advisory mechanisms: the scientific adviser, the adviser for technology missions, and an independent eleven-member Science Advisory Council. The Science Advisory Council advises the Prime Minister on (i) major issues facing science and technology today, and (ii) the health of science and technology in the country and the direction in which it should move.

Since India adopted a planned approach for its development, planning for S&T also became part of the national planning exercise. The Planning Commission plays a central role in formulating the national S&T plan with the involvement of scientists, technologists and representatives of concerned agencies and departments.

The preparation of the five-year S&T plan is an elaborate exercise. Once the overall approach to the main five-year plan has been articulated by the National Development Council, preparation of the sectoral plans is taken up. The responsibility for preparing the plan for the S&T sector is entrusted to the member of the Planning Commission in charge of S&T. The entire exercise involves extensive consultations with agencies, individual experts and non-government organisations (for example science academies). This exercise results in a chapter on S&T in the Planing document. This chapter identifies the main issues to be tackled by the S&T plan, the nature of programs to be taken up by different S&T agencies and an indicative distribution of financial resources.

R&D activities are carried out by institutions that come under Central and State government departments, industrial units, professional bodies, and by university-type structures. Research institutions under central government departments are generally grouped under councils or commissions to provide flexibility and autonomy. For example the Council of Scientific and

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14 Jain, A., 'Science and Technology Policies in India' in P. J. Lavakare and J. G. Waardenburg, Science Policies in International Perspective: the Experience of India and the Netherlands, (London, Pinter, 1989), p. 139.

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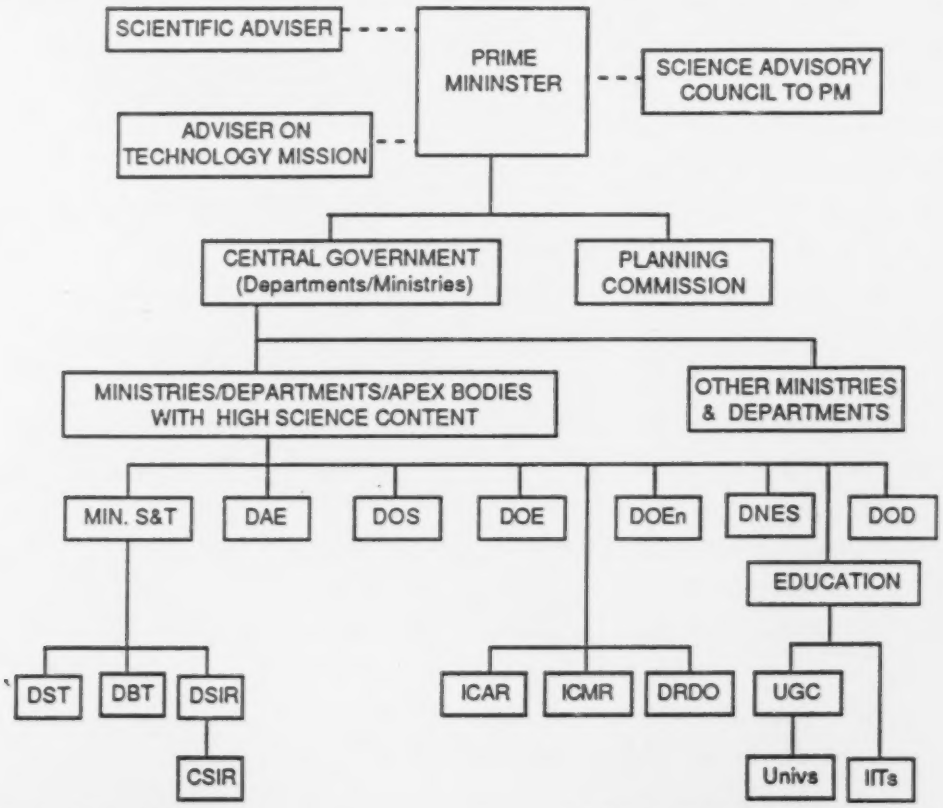
Industrial Research with forty-two research institutions is a registered society with the Prime Minister as its president. Such councils and commissions are headed by scientists and consist of outside experts, representatives of finance, ministries, industry, and other users of research output.

Figure 7 Science and Technology Framework of Central Government



DAE: Dept. of Atomic Energy
DOE: Dept. of Electronics
DNES: Dept. of Non-conventional Energy Sources
DBT: Dept. of Biotechnology
DSIR: Dept. of Scientific and Industrial Research
ICAR: Indian Council of Agricultural Research
DRDO: Defence Research and Development Organisation
CSIR: Council of Scientific and Industrial Research
DOS: Dept. of Space
DOEn: Dept. of Environment
DOD: Dept. of Ocean Development
DST: Dept. of Science and Technology
ICMR: Indian Council of Medical Research
UGC: University Grants Commission
IITL: Indian Institutes of Technology
Univs: Universities

The universities provide trained manpower for research institutions and themselves carry out scientific research. The number of universities has grown from 20 in 1947 to 160 in 1987. Approximately 9 per cent of national R&D expenditure goes to the university system for research. Funds from the University Grants Commission are used mainly for teaching purposes. Project funding schemes of the government departments provide the main resources for research in universities.

The Science and Engineering Research Council Scheme (SERC) was started in 1974 with the objective of promotion in Science and Engineering to cover integrated research programs.

Recently, based on a review of the existing R&D schemes - SERC and the General Research Scheme (GRS), a decision has been taken to integrate the latter into the SERC.

SERC has adopted a three phase long term approach:

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Phase 1: Exploratory Phase (1975-80) to explore new areas and capabilities;

Phase 2: Program Preparatory Identification Phase (1980-85). Identification of programs in the identified areas (thrust areas);

Phase 3: Program consolidation phase (1985-90), capabilities built in areas during the first two phases are being consolidated through setting up units/core groups and specialised facilities and support mechanisms other than SERC.

Thrust areas were identified by the council through a national exercise. For the identification of thrust areas in each discipline, base working papers on each area were prepared, comments sought and finally discussed in a National seminar. As a result, thrust areas emerged in Life, Chemical, Physical and Engineering Sciences. Broad guidelines for a thrust area are:

- Growth of indigenous research capability;
- Challenging to scientists;
- Within national competence and resources;
- Relevant to overall socio-economic development.

Programs in thrust areas were developed by the Council through the Program Advisory Committees (PAC). Each PAC consists of high level experts with a perspective of the areas under the purview of the committee and involving relevant scientific Departments/Agencies. These PACs have the overall major responsibility of developing and monitoring the research activities in the identified thrust areas. In all there are 28 PACs in various disciplines which undertake this responsibility.

Complementary to the thrust being provided to the identified areas, the Intensification of Research in High Priority Areas Scheme (IRHPA) was established to ensure intensification of scientific research in related areas of relevance for scientific and technological development of the country. In IRHPA, the following mechanisms are adopted, which are different from the usual three years project support:

- Setting up of core groups/units around outstanding scientists;
- Identification, formulation and implementation of national R&D programs through involvement of scientists from different agencies and institutions;
- Establishing specialised facilities for well defined research programs in high priority areas to be undertaken by scientists.

Programs in IRHPA are identified on the basis of the exercises undertaken by PAC for identifying thrust areas, and by constituting expert panels and inter-agency groups etc.

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For both TAPs and IRHPA, proposals are called for twice a year and assessed by peer review systems and small committees of experts.

CONCLUSIONS

The methods used for selecting basic research for government support vary greatly between countries, with at one extreme Germany's strong aversion to engaging in the direction of basic research, and at the other the growing pressure in the UK for priorities and accredited performers of research to be determined centrally.

In every one of the nine nations examined in this report there has been a very substantial development of methods for targeting strategic and applied research more effectively to national economic needs. This push for a greater economic pay-off from research has also led some countries to increase their proportions of strategic research at the expense of basic research. There has also been considerable experimentation with new methods to identify strategic research avenues of high promise.

However, the development and application of new selection methods of basic research has generally been approached with considerable caution by research funding agencies and been met with considerable opposition from researchers.

The major vehicle which has been used to influence the direction of basic research has been the setting of priorities. This has generally involved the identification of research areas of special interest through processes involving interaction between the academic members and professional staff of research funding agencies, and varying degrees of consultation with the research community. In some countries fixed sums are allocated for competition in the priority areas; in others, the priorities become simply another criterion to be considered in the evaluation of proposals.

The selection processes being applied to basic research have not undergone very substantial changes. The almost universal approach rests on the assessment of proposals by groups of peers. The selection of peers varies from Ministerial appointment to election, the extent of their involvement ranges from preparing referees' reports to determining allocations, and the closeness of the research expertise of peers to the fields of proposers varies from a precise relationship to a very broad overview.

The other major shift has been directed towards achieving greater concentration of research resources through an increase in the funds allocated to long-term group programs and centres, at the expense of project grants to individuals. One consequence of these larger and longer allocations is that mid-term reviews become feasible. By and large these reviews are conducted by the same peer-based groups responsible for allocations, against conventional criteria of progress and publication.

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PROJECT SELECTION METHODS: INTERNATIONAL COMPARISONS

DRAFT REPORT

INTERNATIONAL EXPERIENCE IN SELECTING BASIC RESEARCH INSTITUTIONS, INVESTIGATIONS AND PROJECTS FOR GOVERNMENT SUPPORT AND THEIR APPLICABILITY TO THE UNITED STATES

Prepared for the Office of Technology Assessment
Congress of the United States

by

Professor Ron Johnston
Centre for Technology and Social Change
University of Wollongong
Australia

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DIRECTING BASIC RESEARCH

The question of who decides, and how, the direction of basic research is not new. On the contrary, the history of modern science can be retailed in terms of endless conflict between the wishes of the seekers of knowledge, (who only assumed the title of scientist in the late nineteenth century) and the interests of the paymasters and would-be users of that knowledge. Apologetic historians of science have cast this as a battle between the forces of light and darkness, respectively. There have been few to speak up from the vantage point of the patron.

The emergence of modern science has been excellently captured as a process which relied more on the achievement of an accommodation between the scientific enterprise and political power than on the truth or applications of the knowledge generated.[1] Given the promissory nature of science, with its requirements of commitments of finances in the present to produce some uncertain benefits in the future, long-term stability could only be achieved by the striking of a social contract. The paymasters would commit themselves to a faith in science and its ability to produce unforeseeable knowledge and benefits in the future, in return for a commitment from the scientists that they would use the public purse frugally and well, and produce a continual, if irregular, bounty for humanity and the state.

A powerful restatement of this social contract was made by Vannevar Bush in 1945 in his celebrated, and influential, Science - The Endless Frontier, in which he argued that governments should fund research but leave the setting of directions and the selection of worthy projects to the scientific community:

> Basic research is performed without thought of practical ends. It results in general knowledge and an understanding of nature and its laws. The general knowledge provides the means of answering a large number of important practical problems, though it may not give a complete, specific answer to any one of them. The scientist doing basic research may not be interested in the practical applications of his work, yet the further progress of industrial development would eventually stagnate if basic scientific research were long neglected.
>
> Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn.[2]

Thus, as a recent OECD report[3] noted:

> Research Councils were set up in most Member countries to allow the scientific community to run scientific research autonomously, to channel priorities from the bottom to the top, and to promote science, either in their own laboratories or by funding university research, or by a combination of the two. Thus, during the twenty-five years that followed the end of the Second World War, and even later, "priorities for science remained largely implicit. Generally speaking (and above all in 'Research Councils') they reflected the gradually shifting interests of the scientific community, as interpreted through the (disciplinary) committees".

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1 J Haberer, **Politics and the Community of Science**, (Van Reinhold, 1983.)

2 V Bush, **Science - The Endless Frontier**, 1946.

3 OECD, **Choosing Priorities in Science and Technology**, SPT(90)2, Paris, 1990

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Under these circumstances, there emerged a two-tier system of resource allocation for science.

The first element of this system is concerned with the allocation of resources between researchers, predominantly within their own fields. It operates at the micro-level and is deeply embedded in the social system of quality control for science. The same social mechanisms which are used to ensure the quality of information which is a candidate for the status of knowledge (Ravetz, 1971) are also used to make judgements about the quality and reputation of a researcher and the likely 'success' of a proposed project. The process which is often referred to as peer review, is essentially private and consensual.

The adequacy of this peer review process has been the subject of close examination recently (see, for example, Mitroff and Chubin, 1979). Criticisms have focussed mainly on issues of lack of consistency, the operation of a 'Matthew effect' favouring established researchers, and the restrictions such an inherently conservative system places on innovation. There has been little suggestion that peer review does not provide the basis for an adequate system of quality control.

The second process has dealt with resource allocation at the macro-level, concerning the budget of science as a whole, and that of particular disciplines or specialties eg. high energy physics or molecular biology. This realm of decision-making is strongly marked by contest, and is conducted in accord with the familiar processes of the accretion and exercise of power that operates in other realms of human and social competition viz politics.

In most instances the micro and macro levels of resource allocation have had, at least in rhetorical terms, relatively little interaction. The most common link is when the intellectual standing and promise of fields and researchers generated in the 'first world' is used as supporting arguments, ie tools or weapons, in the 'second world'. Less frequently, the promises of return generated in the second world have been applied as guidelines for allocation of resources in the first.

The internal process of resource allocation, guarding and reflecting as it does the processes of quality control in science, is central to maintaining the scientific community's end of the social contract viz to produce reliable knowledge. As such it was guarded vigorously. Violations were unusual, and met with all the horror and vigour reserved for the pathological when they did occur. Thus within the community, suspicion of scientific fraud brings down the most extreme approbation. Threats from the outside, in the form of explicit attempts to steer experiments and programs, meet with no less resistance; witness the infamous Lysenko affair, and the extensive moralising that followed,[4] undoubtedly somewhat justified in those totalitarian times.

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4 M Polani, Republic of Science.

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from the paymasters to renegotiate the terms of the social contract. There has been growing dissatisfaction with the accuracy and efficacy of the 'science push' and 'linear innovation' models, and the ever increasing cost of research. In addition, the recognition, perhaps ironic, that new technology, and the knowledge and research that underlie it, are so central to international economic competitiveness that science may be now too important to be left to the scientists to manage, has provided a dramatically new context for the relationship between scientist and paymaster.

As we have argued elsewhere,[7] the new investment model of science is leading to a re-examination of many of the assumed practices in research management and practice, and experimentation with a range of new approaches.

> Thus, as research is critical to economic performance and the level of competition to develop and capture exploitable knowledge is high, it becomes important to attempt to identify the areas and types of knowledge which are most likely to lead to substantial economic returns. This has led to substantial investment in attempts to identify research areas of potentially high pay-off, through **forecasting** and **foresight** activities.
>
> Because of the high level of competition for appropriate research results, the potentially high returns to be obtained from their application, and the high resource cost of producing exploitable research results ahead of the competition, there is a need to concentrate the resources of skill, infrastructure and money in areas with a high estimated return. This has led to the development of **priority-setting**.
>
> The intense competitiveness requires that the research process be managed in a way that maximises its efficiency and productivity. This has led to the emergence of new structured methods of **research management**, based on more explicit **a priori** goal and milestone setting, careful monitoring of progress towards the designated milestones, and regular review of the continuing appropriateness of the goals.
>
> There is also a need to review, after projects and programs have been completed, how effective they have been in achieving their goals and what lessons can be learnt to achieve more effective management of future projects. This has led to the development of explicit techniques for formal **research evaluation** and of **performance indicators** which can be used to regularly assess research performance.
>
> The effective production of potentially valuable research results is, of course, not sufficient to produce economic returns. This process is seen as being so critical in the research-production cycle that a range of new mechanisms and management techniques have been developed to ensure effective linkage and rapid transfer between the two stages. There is continuing experimentation in the development of new and more effective **linkages of knowledge production** and **knowledge exploitation**, within firms, between firms and across the public/private sector boundary.
>
> Finally, the value of exploitable research is such that it has become even more important to seek to capture all the benefits of investment in research. This has led to defensive measures, such as increased intellectual secrecy, restrictions of publication, and more extensive intellectual property protection. More offensive approaches have emphasised the development of the 'complementary assets' (Teece, 1987) of production, marketing and management knowledge to ensure rapid and effective exploitation of research results. There is also a much increased investment in the development and use of a variety of technology intelligence and publication scanning techniques to obtain insights into where competitors are focussing their research, where new 'hot' developments are occurring and where relevant public sector research is being performed.

The lesson to be drawn from this analysis is that the processes of selection of basic research for government support are not immutable. Current practices reflect the terms of the previously negotiated social contract. But neither are they open to unilateral change. The

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7 R Johnston, 'Strategic Policy for Science' in S Cozzens, P Healey, et al, **Managing Science in a Steady State**, 1990.

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paymasters hold the resources, but need the reliable knowledge to be delivered. The scientists alone are in charge of the social mechanisms for knowledge generation, but require the resources to perform. Neither party is in a position to command. The situation is complicated by the fact that there is frequently more than one paymaster, with differing needs, and the scientific community itself is differentiated, offering different knowledge resources, with differing levels of credibility. Under these circumstances the simple model of direct negotiation is made more complex through the possibilities of intersecting and competing interests, alliances, deception and power plays. In simple terms, the models of industrial relations appear entirely appropriate to the scientist-paymaster relationship.

INTERNATIONAL EXPERIENCE IN DIRECTING BASIC RESEARCH

A detailed analysis of the major methods of selecting basic research institutions, investigations and projects for government support in nine countries: United Kingdom, Federal Republic of Germany, France, Japan, Netherlands, Sweden, Canada, Australia and India, has been provided in the Preliminary Report. A table summarising the major methods and procedures is reproduced here.

A number of general findings have emerged. First, however, it is important to reiterate two cautions which were outlined in the Preliminary Report. The first of these was that the nature and boundaries of basic research are themselves in a state of considerable flux. Under the investment model of science, it is possible to conceive of all research as having an application. In a narrow sense, basic research in the sense of research sparked by curiosity is abolished. In a wider sense, the very success of research agencies in effectively directing a range of strategic research programs provides an incentive to seek to extend these methods to the more intractable (ie. difficult, in every sense) area of basic research. Thus one of the methods of selecting basic research for support has been to redefine areas of it as strategic, and open to the methods applicable to mission-oriented research, viz. targetting, milestones, management by objectives, performance objectives, etc.

The second caution is a traditional one concerning the applicability of models drawn from other countries' experiences. The institutional structures of policy-making and funding are critical determinants of the way in which governments support basic research and provide a powerful setting to which any new methods of selection must be adopted. Hence any system operating in another country will need to be refashioned to fit local structure, culture, practise and distribution of power.

Allowing these cautions, a number of interesting generalisations have emerged.

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TABLE 1 RECENT APPROACHES TO MORE SELECTIVE SUPPORT OF BASIC RESEARCH

Country/ Agency*	Steering Device	Priority Setting		Implementation/Selection		Status
		Method	Decision-Makers	Methods†	Decision-Makers	
UK						
UFC	Selective core-funding to universities and to departments	-	-	Review of departmental performance against 4 criteria	Council part-time academics) and department officials	Government Appointed
ABRC	Interdisciplinary Research Centres (1988)	Submissions and internal discussion	Panels	Open Proposals	peer panels and referees	"
SERC	Directorates (7 years)	Internal discussion	Council (peers and users)	Open proposals	peer panels and referees	"
	Program (5 years)	Internal discussion	Council	Open proposals	peer panel and referees	"
ESRC	Centres (5-15 years)	Internal discussion	Council (peers and users)	Invited Proposals	Board of peers, and users	"
	Programs (5 years)	Internal discussion	Research Grants Board	Open proposals	Board of peers and users	"
FRG						
DFG	Priority programs	Bottom-up discussion	Researchers	Invited proposals	DFG Senate (peers)	Elected
MPG	Priority research areas Institutes	Bottom-up discussion -	Researchers -	Invited proposals Open proposals and extensive evaluation	peer review MPG Senate (peers)	" "
FRANCE						
MRT	Programmes Mobilisateurs	Identification of generic technologies	CRE* and department officials	Negotiated proposals	Department officials and peer panels	
CNRS	Annual strategic plans	Identification of leading researchers	Council peers and department officials	Invited proposals	Peer panel and referees	Elected and appointed
JAPAN						
Monbusho	Priority Research Areas (3-6 years)	Identification of areas of strong scientific opportunity & social need	Monbusho Science Council	Open Proposals	Science Council and peer panels and referees	Appointed
	Specially Promoted Research (5 years)	Selection of 2 key fields and program leader	Science Council	Proposal by selected program leader	Science Council	"
NETHERLANDS						
MES	Conditional Funding of university research	-	-	Evaluation of proposed major research programs by experts and bibliometric measures	MES (government department) and advisory panel	"

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Netherlands cont.						
NWO	Second Flow Funding	Identification of future needs and priorities	RAWB * (appointed) and NWO	Open proposals	NWO (peers) and referees	Elected
SWEDEN						
Cabinet	Research Policy Bill	Wide consultation, symposia, reports over 2 years and government department, scientific societies, researchers	Effective consensus	-	-	-
NFR	Consortia	Invitations to consortium of university departments to propose interdisciplinary programs	Council (appointed and elected)	Open proposals	Council andForeign referees	Appointed an elected
FRN	Priority fields	Identification of societal problem, then elaboration of research needs and opportunities	Council and Committees (research and users)	Invited proposals	Council and foreign referees	"
CANADA						
ISTC	Decision Framework for Science and Technology	Computation of agencies' research priorities identifying strengths and gaps	ISTC	-	-	-
ISTC (Innovation)	National Centres of Excellence	-	-	Open proposals judged against criteria of excellence and industrial relevance, and network formation	ICST Committee (government officials and researchers) and national and international referees	Appointed
NSERC	Strategic Grants Program	Identification of 30 themes in the 3 national priority areas by consultation, analysis, workshops	Science Council of Canada	Open proposals	Peer panel and referees	"
SSHRC	Strategic Research Program	Biennial Seminars and commissioned reviews	Council (department officials and researchers)	Open proposals	Peer panel and referees	"
AUSTRALIA						
ARC	Special Research Centres			Open proposals	Peer panels and referees	"
	Priority Research Areas	Submissions consultation and internal	Council (researchers)	Open proposals and competition against all other applications	Peer panels and referees	"
NH&MRC	Priority Research Fields	Internal discussion and consultation	Council (reseasrchers) and poanels	Open proposals	Peer panels and referees	"

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INDIA						
National Development Council	Five-year Science and Technology Plan	Expert reports, consultation, draft reviews	Council (government officials)	-	-	-
SERC	Thrust Area Programs	National exercise of working paper preparation, review, National Seminar	Council and Program Advisory Committees (scientific experts and government officials)	Invited proposals	Council and peer panel and referees	Appointed
	Intensification of Research in High Priority Areas Scheme	Thrust area identification exercise	PACs	Proposals invited from outstanding scientists	Council and peer panel and referees	Appointed

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* UFC Universities Funding Council
ABRC Advisory Board of the Research Councils
SERC Science and Engineering Research Council
ESRC Economic and Social Research Council
DFG Deutsche Forschungsgemeinschaft (German Research Society)
MPG Max Planck Gesellschaft (Max Planck Society)
MRT Ministry of Research and Technology
CNRS Centre National de la Recherche Scientifique (National Centre of Scientific Research)
CPE Centre de Prospective et Evaluative (Prospects and Evaluation Centre)
Monbusho Ministry of Education, Science and Culture
MES Ministry for Education and Science
NWO Netherlands Organisation for Scientific Research
RAWB Science Policy Council of the Netherlands
NFR National Science Research Council
FRN Council for Planning and Coordination of Research
ISTC Industry, Science and Technology Canada
InnovAction Canadian Strategy for Science and Technology
NSERC Natural Sciences and Engineering Research Council
SSHRC Social Sciences and Humanities Research Council
ARC Australian Research Council
NH&MRC National Health and Medical Research Council

† Open proposals - a general call for proposals from all who are eligible, usually with broadly specified criteria for assessment.

Invited proposals - proposals invited from selected individuals or research teams.

Negotiated proposals - identified researchers work closely with research-funding bodies to develop a proposal which meets the requirements.

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In every one of the nine nations examined in this report there has been a very substantial development of methods for targetting strategic and applied research more effectively to national economic needs. This push for a greater economic pay-off from research has also led some countries to increase their proportions of strategic research at the expense of basic research. There has also been considerable experimentation with new methods to identify strategic research avenues of high promise. However, the development and application of new selection methods for basic research has generally been approached with considerable caution by research funding agencies and been met with considerable opposition from researchers.

One interesting insight is that the extent of direction of basic research is apparently directly related to the need to do so; in other words it is a factor of the available resources to support basic research. In countries like Germany and Japan where there appears to be little shortage of funds to support basic research there is no great enthusiasm for more central direction of research, even though both these countries have elaborate mechanisms for targetting strategic research and linking it to industrial needs and commercial opportunities.

At the other extreme, countries who are suffering a significant squeeze on funds available for basic research, and who have been less successful in establishing mechanisms for pursuing an adequate level of strategic research with a strong application orientation, eg. UK, Canada and to a lesser extent, Australia, are pushing hardest in achieving a greater government influence over the direction of basic research.

The simple (perhaps over-simple) conclusion which can be drawn is that attention should be directed to building an adequate capability and management system for strategic research before attempting to shape basic research. However, in the absence of the former it is perhaps politically inevitable that the latter should be subjected to close scrutiny. This conclusion is reinforced by acknowledgement in a number of countries that their zeal to link research to socio-economic objectives may have been excessive in the 1980s, and they recognise the need to increase their commitment to basic research.

The major vehicle for influencing the direction of basic research has been priority-setting. A recent OECD report[8] has noted the broadening of the concept of priorities to include not only 'thematic' priorities but also 'structural' priorities. Indeed they argue that the two are "indissolubly linked". Thematic priorities cannot be implemented without adequate structural support.

A significant level of structural priority setting has been identified in the nine countries. The major form of structural priority is the achievement of greater concentration of research resources through an increase in the funds allocated to long-term programs and Centres.

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8 OECD, op cit.

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Thematic priority-setting has also been increasingly applied by the majority of the countries, though with the exception of the UK such priorities do not represent more than 20 per cent of research agency budgets. These thematic priorities have been established at a number of levels, ranging from the national to research agency, set of disciplines or problem areas to individual disciplines. Martin and Irvine's[9] classification of holistic, macro, meso and micro levels, and the OECD's[10] political, strategic and operational levels are useful schemes for distinguishing the different levels of priority setting, and the different approaches and mechanisms that are appropriate at each level.

Examination of the mechanisms and experiences of the nine countries in developing and implementing new approaches to the direction of the basic research has enabled four distinct models of priority setting and implementation to be identified:- structural, thematic disconnected, thematic connected, and systematic.

i) Structural - in the UK, Netherlands, Canada, and to a lesser extent, Australia, the emphasis has been on the application of structural priorities. These have generally followed the principles of concentration, either by allocating more of the resources in larger units, and/or by increasing the proportion of research funds distributed on a competitive basis. A process of concentration may be appropriate where human and material resources have become excessively diffused or fragmented. However concentration alone carries the danger of freezing national capabilities around present, or worse past, historical strengths. This would not appear to be an appropriate mechanism, of its own, to identify and respond to challenges and opportunities of the future.

The British system would appear to have particular defects in the extent to which the basis for implementation of structural priorities and determination of thematic priorities, is conducted behind closed doors by an appointed and non-representative elite. Such a non-participative approach would appear to have grave dangers of engendering hostility and resentment rather than the consensus required for effective priority setting and implementation. To this author it reflects the class system of the country.

In contrast, in the Netherlands bibliometric measures have been developed to provide a public and objective basis for structural priorities, together with an open and transparent system of evaluation.

ii) Thematic Disconnected - this model is evident in the UK, Canada, Australia and for some programs, Japan. It describes the system in which the priority setting system is

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9 B Martin & J Irvine, Research Forsight, Pinter, London, 1989.
10 OECD, op cit.

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effectively disconnected from the priority implementation process. In each of these countries the establishment of priorities occurs in a relatively closed process, but the implementation is through traditional methods of an open call for competitive proposals, to be evaluated by peer panels together with the assistance of referees reports. Such a system has the virtues of combining thematic priority setting with leaving researchers their freedom to develop their own research programs to be evaluated by peers. However there is a real danger that the priorities would serve as little more than signposts for labelling, and the level of implementation of the priorities could remain quite low. The deep resistance of the Canadian scientists to just such a system would appear to reflect this kind of problem.

iii) Thematic Connected - this model describes systems in which the priority setting and implementation mechanisms are strongly connected. Within this model there are two different types. The Federal Republic of Germany represents a 'bottom-up' form of the Thematic Connected model, in which the scientists themselves are primarily responsible for identifying thematic priorities, but once established, it is essentially the same researchers who are invited to prepare proposals according to negotiated criteria.

The other type is the 'top down' Thematic Connected model, which operates in France, Japan, India, and in the FRN in Sweden. In these cases the thematic priorities are identified by research agencies, composed variously of researchers, users, government officials and community representatives. Once established the research agency works closely with identified individuals and groups to develop proposals which meet the requirements as determined by the agency.

The Swedish FRN provides a positive model of building basic research around societal needs through a system of problem identification followed by an articulation of relevant research disciplines and specialties, and invited proposals to develop relevant research programs related to the problem in these disciplines.

The top down Thematic Connected model has considerable advantages in terms of efficiency and effective implementation. However it is more likely to be acceptable in a nation where a culture of cooperation is well established. In a more competitive culture this system could be seen as being too readily open to nepotism and political favouritism.

iv) Systematic - this model is best represented in Sweden and France, and perhaps India. What makes each of these countries' systems for directing basic research is the extent to which they have approached it systematically. In Sweden an extraordinarily intensive process of consultation, intelligence gathering, preparation and review of position papers and symposia leads to the drafting of a three-yearly Research Bill

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which sets the national directions in research. While such a process is obviously resource-intensive, it effectively commits all research agencies and researchers to a concerted set of national research objectives. It obviously represents a major exercise in consensus generation which might be far less successful in countries where consensus is not a strong national feature.

Similarly in France, a major systematic effort is being directed to establishing a national capability in research intelligence, foresight and evaluation. A wide range of foresight exercises[11] have been conducted and two public sector think-tanks - the Centre de Prospective et d'Evaluation (CPE) and the Observatoire des Sciences et Techniques (OST) - have been established by the Ministry of Research and Technology to produce indicators, conduct evaluations, provide research intelligence and create a national capacity in research evaluation. The work of these units is starting to feed effectively into decision-making in MRT and CNRS.

Finally, this survey has found that the formal application of ex-post evaluation in the selection of future projects for funding remains relatively rare. However with the increase in the establishment of programs, directorates and centres which have an extended life (eg. SERC Directorates, ESRC Centres, MPG Institutes, Monbusho Specially Promoted Research, ISTC National Centres of Excellence, ARC Special Research Centres and SERC Thrust Area Programs), reviews during the life of the Program to determine future funding and to advise on improved performance of the research unit have become much more common.

APPLICATIONS AND IMPLICATIONS FOR THE UNITED STATES

There are a number of features special to the US research system which will need to be borne in mind when considering the applicability of the experiences of the nine countries surveyed.

- In all of the nine countries surveyed, governments pay for researcher salaries, support, equipment and materials through general institutional grants which are supplemented by competitive funds for research projects. In contrast in the US, competitive support for specific research projects is the primary funding mechanism for academic research. Thus a strong concentration of resources could decimate academic research and perhaps have serious implications for the quality of university teaching.

- In the vast majority of cases in the nine countries individual researchers and research teams have only one possible source of funds to support their research beyond that

11 Martin & Irvine, op cit.

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available from institutional grants. If they are unsuccessful, or do not 'fit', there is nowhere else to turn. In the US there is a plurality of potential funding agencies for almost every researcher.

- In the US there is a very high level of absolute funding for basic research, comparable with that of FRG once defence research is excluded. The argument that applies in the FRG may be relevant, ie. priority setting is not necessary; with enough funds the serendipity model works very well. It is notable that the outbreak of discussion over priority setting in the US in 1988 was raised by competing, hugely expensive, big science projects. All nine countries have shifted almost all of their big science into international cooperative ventures.

- The system of research grant administration, with its heavy reliance on 'rotators', ie. academic researchers spending two years in research administration, is unique, and allows a far larger role for research administrators than is practised (or at least admitted) in the nine countries. This represents a very considerable basis for consensus development over thematic priority setting.

What than are the lessons for the US? While the resources available for basic research are large and provided by a range of research agencies, the strategic importance of research and the appropriation of its results would suggest there is a case for strengthening the capability to direct basic research.

The structural priorities model would not appear to address an important problem in the US. However both the Thematic Disconnected and the Thematic Connected models might be appropriate for consideration by NIH, NSF, DOE and NASA. The former model is likely to be most appropriate when the identified thematic priority area is relevant to a range of well-established disciplines. Where a thematic priority is opening up a very new area, or sitting at the boundaries of a number of disciplines, the more directive Thematic Connected model might prove more effective.

However what is most important is that the research agencies set about the development of a capability for directing basic research in a systematic way. It is important that these agencies and their constituency, the researchers, go beyond the view of thematic priorities as a list of research topics with a somewhat more favoured status (or star rating). It is not a matter of choosing five star topics. Even less is it of central concern whether they are exactly 'right'. Rather with the rapid changes in science and technology, and economic and societal needs, there is a need for a flexible system which can continually re-asses priorities. Given the structural needs of any discipline, there will be a need to maintain a strong core and to focus on relationships with other fields, and the relative balance of supporting fields.

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The recent OECD report[12] recommends the development of a science and technology watch - "the set of activities involving the acquisition, analysis and evaluation of information of all kinds on which decision-making and priority setting are based". To be effective such a watch needs to be strongly interactive, in all senses of the word. Scientists and research administrators need to contribute their information to the watch, and draw from it to shape their own decisions at the strategic and operational level. It is in the last respect that such a watch would differ from the discontinued 'Science and Technology Outlooks'.

The watch should not be primarily a technical device or challenge. Rather it is a social mechanism for increasing the understanding of the role and effect of priority setting in contemporary science and for establishing the communal ability to take such decisions and to manage them into effectiveness.

12 OECD op cit.

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Policy Uses of "Evaluation of Research" Literature

Harvey Averch
Department of Public Administration
Florida International University

Prepared under contract to the Office of Technology Assessment
July 1990

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The Practice of Research Evaluation Around the World-1990

H. Averch[1]

Introduction

In 1986 OTA reached the following conclusion concerning measuring the returns from public investments in R&D.

> In summary, OTA finds that the metaphor of research funding as an investment, while valid conceptually, does not provide a useful practical guide to improving Federal research decisionmaking. The factors that need to be taken into account in research planning, budgeting, resource allocation, and evaluation are too complex and subjective; the payoffs too diverse and incommensurable; and the institutional barriers to formidable to allow quantitative models to take the place of mature, informed judgment.[2]

Four years have passed since OTA announced this conclusion. Demand for research evaluations has increased in all countries that make significant investments in R&D. The reasons for increased demand are the same: budgetary constraints; greater accountability to sponsors; and the desire for increased rationality in decision making.[3] The practice of research evaluation has been partially legitimized by the formation of evaluation units

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[1]Department of Public Administration, Florida International University. This report submitted in partial fulfillment of OTA Contract N3-2385.0 Len Lederman of the National Science Foundation staff provided valuable comment on the draft version of the report.

[2]U.S. Congress, Office of Technology Assessment, Research Funding as an Investment: Can we Measure the Returns? (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-TM-SET-36, April 1986), p. 9.

[3]Even countries that do not make significant absolute investments claim they evaluate. See unpublished proceedings of the ECE Seminar on Evaluation in the Management of R and D, April 3-7, 1989. Finland, Hungary, and Poland report on their evaluation efforts.

in many R&D funding agencies.[4] Research evaluators and designers of science impact indicators have carried out substantial amounts of additional technical work on measuring scientific and technological performance. There have been refinements in existing methods for evaluating R&D impacts ex post. Nevertheless, examination of recently published and unpublished literature on research evaluation methods between 1985 and 1990 shows that the OTA's conclusion still stands. Since 1985, no breakthrough methods of any variety have been invented that more definitively reveal the ex post scientific or social value of past research investments.[5] While the computer permits greater use of ex ante project selection methods and ex post evaluation methods, the evidence is sparse that there is much payoff to public or private sector R&D administrators from making greater use of them.[6]

Consequently, R&D administrators have little incentive to use current evaluation technologies for ex ante decisions about R&D level or allocations. This lack of incentive is certainly consistent with the published evidence on their use. R&D administrators, do use ex post evaluations for political and organizational purposes, for example, to convince sponsors that they are interested in rational decision processes and

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[4]The scientific community still believes that evaluators per se have no special skills or insights compared to working scientists. Consequently, evaluation offices usually have relatively low organizational status and acceptance among working scientists.

[5]By definitively reveal I mean that evaluation outcomes, whether positive or negative, will (1) be accepted without lengthy technical and political disputes between sponsors, funders, and clients and constituents, and (2) they provide unambiguous direction in resource allocation or other kinds of decisions.

[6]K. M Watts and J. C. Higgins, "The Use of Advanced Management Techniques in R&D," Omega, vol. 15, 1987, pp. 21-29. This survey, consistent with past surveys, shows that R&D administrators prefer simple, transparent methods of project selection.

that they are funding good work.[7] However, the research evaluation literature between 1985-1990 contains very few demonstrations that evaluation makes any difference at all to the critical decisions about the level and allocation of scarce scientific and technical resources.[8]

Design of the Paper

This paper consists of three parts. In the first part, I describe evaluation practice and process in the United States, Western Europe, Japan, and Australia. In the second part, I consider incremental improvements in research evaluation methods since the 1986 OTA review. In the third part, I suggest that research evaluation faces certain inherent limits that make it unlikely that (1) average or incremental monetary or informational returns can ever be measured with precision and that (2) even if they could be, they are

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[7]Whenever queried by sponsors, R&D administrators can cite evaluations in their agency. However, sponsors rarely press hard and ask for demonstrations of use in decisionmaking. All parties to R&D funding transactions know the answer would be embarrassing. But evaluation activity has signal and symbolic content that are important to agency welfare. See M. S. Feldman and J. G. March, "Information in Organizations as Signal and Symbol," Administrative Science Quarterly, Vol 26, 1981, 171-186 and M. S. Feldman, Order without Design: Information Production and Policy. (Stanford: Stanford University Press, 1989).

[8]The New York Times, vol. CXXIX, Sunday, May 27, 1990, pp. 1 and 12, reports that increasing cost and capital intensity of "large" science are squeezing out "small" science. As usual in times of budget austerity, the scientific community wants to increase resources to the point where all "good" science can be funded. It has not proposed evaluation strategies to free up resources by weeding out "bad," ineffective, or inefficient science. The community has trouble distinguishing these things at the time resource allocation decisions are made. It only knows these things in the very long run. However, it claims simultaneously that research proposals and the ex ante peer review of those proposals guarantee good and cost-effective science ex post. But it is well known that the peer review rarely addresses the cost-effectiveness of research designs and whether desired information can be produced more cheaply.

not likely to be used seriously. Thus, the search for measures of substantive returns on their investments probably should receive less emphasis from R&D sponsors than in the past. Basic research evaluation, rather than a means of computing returns on past public investments or a guide to prospective investments, may have to be reconceptualized as an organizational process that keeps R&D funding agencies sharp and on their toes just as environmental impact statements force agencies to consider the impact of their programs on the environment.[9]

Research Evaluation Practices and Processes

Table 1 summarizes the characteristics of the evaluation process among major scientific and technological powers. Countries are on the rows and the columns contain important criteria and processes. For perspective, I have also included evaluation practice by the EC and by Hungary, a relatively scientifically advanced country in Eastern Europe. Now major powers have many R&D agencies. So the entries denote an average derived from different agency reports and studies.

By examining the entries in the cells, the reader can obtain an overview of current evaluation practice among major science powers. For example, reading down the Government Standards column the reader can learn that no countries have yet

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[9]See, for example, S. Taylor, Making Bureaucracies Think: The Environmental Impact Strategy of Administrative Reform. (Stanford, Calif: Stanford University Press, 1984); E.N. Goldenberg, "The Three Faces of Evaluation, Journal of Policy Analysis and Management, vol. 2, 1983, pp. 515-525; R. V. Bartlett, Policy Through Impact Assessment: Institutionalized Analysis as a Policy Strategy. (New York: Greenwood Press, 1989).

developed formal standards that research evaluators must meet, although a number of them say they want to follow "best practice." [10]

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[10]Evaluators are aware each particular technique has important frailties. Most of the countries have accepted the view that it is important to use multiple methods, in the belief that they all point to similar conclusions, the level of confidence is higher. They implicitly reject the notion that if each method has a reliability of less than one, putting them together may result in lower reliability than single methods. Reliability seems to be additive in this view, rather than multiplicative.

Government	(1) Methods of Evaluation	(2) Type of Research Evaluated	(3) Reported Utility	(4) Central Evaluation Units	(5) Government Standards	(6) Reporting
United States	All (varies by agency: peer review/bibliometric/rate-of-return/marginal productivity/substantive outcomes	Projects/Programs	Persuasion/ Budget discussions/ Quality control	Yes in line departments but none in Executive Office of President.	No; but informal notions of best practice	Variable (some made public; some held privately)
Nordic governments	Peer review/substantive outcomes	Projects/programs/	Quality control/resource allocation		No	Public
France	Peer review/ Bibliometrics/substantive outcomes	Universities and Grand Ecoles/ Public research institutions/ Energy and material research programs	Consistency with national plans	Agencies with research missions	No. But evaluations required by law/To include socio-economic aspects where appropriate	Variable (some made public; some held privately)

Government	(1) Methods of Evaluation	(2) Type of Research Evaluated	(3) Reported Utility	(4) Central Evaluation Units	(5) Government Standards	(6) Reporting
United Kingdom	Peer review citation/publication/ rate-of-return/patents/ checklists/market outcomes	Large projects/- Programs/Universities/Laboratories	Improve policy decisions	Assessment Office within Cabinet office; Department of Trade and Industry has central unit.Some departments have Chief Scientists and Departmental Review Committees	Definitions of good practice	Some public
FRG	Economic and market indicators/ Ex post peer review for basic research projects/ Special committees for programs/Evaluations of disciplines/bibliometrics/patents/market outcomes	Large and small projects and programs	Improve policy decisions	BMFT has central unit	No	Some public

Government	(1) Methods of Evaluation	(2) Type of Research Evaluated	(3) Reported Utility	(4) Central Evaluation Units	(5) Government Standards	(6) Reporting
Japan[11]	Consistency with plans developed by "foresight"/Market tests for applied commercial projects	Projects/priority programs	Planning	New central science policy unit has some evaluation responsibilities	No	Some public
Netherlands	Peer review/Publication-citation indicators for basic research/Client satisfaction or utility for applied projects/Profits earned from research contracts	Projects/basic research programs, universities, industrial research	Insure consistency with plans/Assist with allocation decisions	Yes in public agencies and universities	No	All public

[11]Most of the literature on Japan discusses their R&D planning processes and the use of "foresight" methods. There is less open literature on ex post evaluation. On foresight, see J. Irvine and B.R. Martin, Research Foresight: Creating the Future (The Hague: Netherlands Ministry of Education and Science, 1989).

Government	(1) Methods of Evaluation	(2) Type of Research Evaluated	(3) Reported Utility	(4) Central Evaluation Units	(5) Government Standards	(6) Reporting
Sweden	Similar to Netherlands, but uses international peers	Projects, basic research programs, universities, industrial research	Allocation decisions/ Almost the only country that consistently uses evaluations for resource allocation purposes		No	All public
EC	Peer review (but includes users)/ Bibliometric/Industrial spinoffs/Commercial pay-offs/Public sector use	Joint programs with cost-sharing	Design of future programs	Yes but with advisory groups	Developing standards of good practice	1000 copies to scientific commisrions/scientific journals /national governments
Hungary	Peer review/Bibliometrics/Market tests for applied research	Basic research/Research to benefit industry	Grants/bonuses to research performers/ Appraisal of economic outcomes	In Academy of Science and State Committee for Technical Development	No	Some from Academy of Sciences

Recent Advances in Measuring Returns

Since 1985, advances in all methods of measuring returns to basic research have been modest. Governments may not have devoted sufficient resources to developing methods.[12] Alternatively, the research evaluation field may be up against its inherent limits and simply cannot progress much more or much faster. Below are some notes on the marginal advances made since 1985.

Economic returns

Consumers' surplus: Given an ordinary demand curve, economists can now produce the exact compensated demand curve required for accurate computation of consumers' surplus and, therefore, average rates of return. Specification of demand curves remains a problem especially for new products. Estimates are sensitive to the form of the demand curve, and exiting data permits plausible alternatives. Furthermore, economists still have no way to compute the private or social returns from having entirely new products come on the market.

Production functions: Sophisticated econometric techniques for estimating production functions continue to be produced. Since the marginal value of research for output or growth in output is heavily dependent on down stream events, production functions should probably take on interactive forms and include demonstration and marketing inputs, but no such functions have been reported.

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[12]For example, the NSF with a budget of almost $2 billion dollars does not have a program designed to improve R&D planning, budgeting and evaluation.

Alternatively, R&D has to be embedded in fuller models of information flow and economic behavior, and none have yet appeared.

Bibliometrics and patent counts: Sophistication about bibliometric and patent counting techniques has increased, but their import still needs to be pinned down. Bibliometricians continue to refine and correlate existing data bases, but they do not relate bibliometric flows to social and economic payoffs. Some effort has begun to relate the worth of scientific work by looking at their references in patent literature.[13] However, the use or value of patents has not been addressed nor has strategic gaming inherent in decisions to disclose via patents.

Quantitative project selection methods: Literally hundreds of methods exist in industry for guiding investments ex ante. Given the large, but cheap increases in computing power, elaborate goal programming and analytic hierarchy (AHP) models have become common recommendations by management analysts for deciding on ex ante investments. But even the most mathematical and rigorous techniques remain very sensitive to subjective and highly uncertain estimates of technical and market success. Some of the techniques such as ROI's, impact matrices, or check lists can be used to estimate ex post values. But few ex post studies have appeared in the open

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[13]See W. B. Ashton and R. K. Sen, "Understanding Technology Change Using Patent Information," 1986, unpublished paper,

literature.[14] In any case, a sequence of studies on the use of quantitative techniques shows industry prefers simple, transparent methods.

Industry, of course, is not as committed and bound to ex ante judgments as the public sector. Industry generally starts many more projects than can be finished, but it uses incremental gains in information to stop the least promising. The future resources saved are then reallocated to the intensive, downstream efforts required to make the more promising projects payoff. Few, if any, government R&D agencies can behave in this way, since sponsors consider stopping projects, not as a necessary cost of gaining valuable information but as waste. Managers who engage in such efforts are almost never rewarded or promoted in government as they are in industry. So projects and programs in government that evaluation reveals as not meeting objectives often get more resources.

Some inherent limits in computing returns

Individual projects: Each and every method for assessing the worth of projects has inherent and irremediable weaknesses. If weaknesses always counterbalanced each other, then we might use different methods simultaneously to assess worth, and, thereby, increase our confidence if outcomes were to go in the same direction. But we have no way of knowing whether the weaknesses combine to give an even falser picture than one method would or whether methods do, in fact, counterbalance each

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[14]See E. Mansfield et al., "Social and Private Rates of Return from Industrial Innovations, Review of Economics and Statistics, vol 61, 1979, pp. 49-52. Here the authors show, in a high proportion of projects and products, that if investors had known private returns would turn out to be as low as they did, they would never have made their investments even though social returns were high.

other. Thus, the currently fashionable prescription for multiple method approaches may not be well grounded. In any case, multiple methods increase the costs of evaluations to the point where information gained about ex post merit may not be worth the cost, given the high probability that the results will not be used for decisionmaking.

Assessing programs and portfolios of research: In reality, R&D funders at middle and top levels rarely care whether the returns from particular projects are positive or negative. They say they are not in "retail" trade.[15] What they care about are the average and marginal returns from investments in programs and related project sets.[16] Few single projects, regardless of their publication and citation rate, will influence the trajectories of science one way or another.[17] The question is whether R&D administrators can select streams of projects or portfolios of projects that result

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[15]Average research grant sizes in civilian R&D agencies are quite small, perhaps less than $100, 000 per year, and they make hundreds or thousands of such grants each year. Obviously, if a project absorbs hundreds of millions of dollars or billions as in the case of the SSC or Human Genome projects, administrators are on the line. However, in these cases, ex ante and ex post evaluation techniques will have little persuasive power in the face of technical and political stakeholders who are well organized and powerful.

[16]Most R&D administrators, in reality, care most about the effect of their programs on the size of their future budgets. They will be judged, not on the incremental informational value of the projects they funded but on whether they persuaded sponsors to provide significant budget increases for their agency. Ex post, what matters is not information produced or improved social and economic outcomes, but the defensibility and financial accountability of the process used in making allocations.

[17]Most single publications receive one or two citations at best. So most projects are going to produce few aggregate citations.

collectively in reasonable scientific merit or produce social and economic benefits beyond costs.

Projects within portfolios are nominally connected to themselves and to other projects outside funded by others. But there are no credible methods for aggregating project worth up to program worth. For example, suppose a government funding agency generated payoff from five out of a hundred projects in some portfolio it constructed. Does this mean that the funder selected a bad portfolio? It is hard to say. For some programs a few, very high payoff projects may be an appropriate result, especially if they complement private sector efforts.

Ex ante, the funder may have used the best selection algorithms available. However, funders, at least for research in the assistance mode, have little control over the execution of the projects they support. So lack of payoff may have little to do with the intrinsic merits of project design and substance and more to do with the differential competence and efficiency of performers. But no funder can identify very well the most competent and efficient of performers. And they certainly could not decide to allocate all their resources to the most competent even if they wanted to, since "have nots" would go to Congress to protest about inequities.

Incentive incompatibility: Evaluations put R&D funders at risk, especially evaluations of programs that have used up significant amounts of resources. Positive or negative findings can easily be challenged by constituents and sponsors. Relatively minor negative findings receive the most attention by the OMB, the Congress, and the media. The more serious the intent to use evaluations to guide decisions, the

more serious the challenge. Such use threatens long standing accommodations and tacit working agreements common among funders and their clients. For example, physics research traditionally receives a relatively fixed proportion of the NSF budget, about 20-22 percent. An evaluation that suggested that, at the margin, there was greater payoff in chemistry investments, that the physics budget should be reduced, and the chemistry budget, increased would induce a "war" inside the agency and between the chemistry and physics communities outside. Such a war would be unseemly for the whole agency and, perhaps, threaten the whole budget.

Limited action implications: Assume that technically valid evaluations can be produced. In the case of public programs with firm measures of performance, negative summative evaluations suggest termination. But for programs whose output is information the situation is highly problematic. Information volume and quality might be low, but this may be because the overall level of resources is too low or too high. Or a program may have technical inefficiency due to poor management. Or the lack of results may itself have high scientific or technological value, giving clues on where not to look, but evaluators and sponsors weigh positive results more highly .

In any case, historically, science and technology are full of sudden reversals about the value of information produced by past research. Testing hundreds of compounds for superconductivity was, until recently, not considered high grade science, but routine science. And any evaluation of this work would have suggested that this kind of science was not worth much investment. Similarly, the funding of the early

molecular/RDNA projects were not done because anyone expected high payoffs. Certainly, no one at the time imagined a whole biotechnology industry as the result. Thus, the ability of research evaluations to provide credible estimates of the **incremental** informational benefits to be gained from **additional** funds is weak. So it is better to use an insurance principle and spread resources very thinly to insure that no reasonable bets are overlooked.

Of course, if resources are too limited, then particular projects will fall below the critical levels necessary for research advances. If funders knew why evaluations come out the way they do, and if the reasons why had something to do with actions a funder can take, and if funds were the only major obstacle, then a funder might want to do evaluations and channel resources according to results. But research evaluators and sociologists of science have not delivered this kind of knowledge. Consequently, it is in the interests of decision makers to charter evaluations as signals and symbols of rational decision making, and then ignore them in actual decisions.

Research evaluation as an organizational control process

Among government-funded investments, R&D is among the most uncertain about the timing and extent of payoff.[18] Thus funders may have to look not at results and payoffs--these are not really controlled by funders--but to whether or not they have

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[18]I make the traditional distinction here between uncertainty and risk. For risky projects, we have enough information to define probability distributions over important events, and so we can come to some overall estimate of returns. For example, it is fairly easy to estimate the ex ante and ex post returns from building a dam. In the case of R&D, we do not have sufficient information, since the worth of the investment will only become clear over time as the scientific and entrepreneurial communities piece together the results from many different research portfolios.

designed reasonable processes of allocation. Reasonable processes means that decisions are not made by rote, that questions and uncertainties are thoroughly explained and explored.[19] Summative and formative evaluations for R&D, to use the jargon of the mainstream program evaluation profession, can help in raising difficult and critical questions and uncertainties, but they cannot certify worth. Thus, R&D evaluators, like other policy analysts have to be prepared to bite the hands that feed them. Owners of these hands need to be willing to be bit. Such willingness comes harder to R&D administrators than other public administrators. Judgments about the adequacy of their performance focus mainly on budget acquisition and very little on budget effectiveness achieved in terms of desirable social or scientific outcomes.

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[19]Students of organizations have derived a whole set of recommended behaviors when inputs, outputs, and production relations are all ambiguous. For one approach, see I. L. Janis, Crucial Decisions: Leadership in Policymaking and Crisis Management (New York: The Free Press, 1989). Janis advocates "vigilant" problem solving for issues where the stakes are high. A vigilant problem-solving process is one that asks a lot of critical questions and gets them answered and then generates effective action to get the most preferred alternative implemented.

Annotated Bibliography on Evaluation of Research, 1985--1990

H. Averch[1]

This annotated bibliography contains relevant literature on research evaluation appearing after 1985. It covers work published in journals and government documents. There are 147 listings.

A * denotes a significant incremental contribution to the literature or attempts to explain critical assumptions and values in research evaluation.

A ** denotes a case study report or summaries of case studies. By a case study I mean an analytic description of what was done and what happened in an actual evaluation. In particular, a case study should describe the use and utility made of the evaluation. There are very few case studies reported. The literature is very sparse in reporting how actual evaluations have been conducted and highly reticent on use and utility.

On occasion, the literature reports that evaluations were read by decision makers, but it does not go on to show whether evaluation made any difference in resource allocation or agency practice. Defenders of research evaluation argue that it can inform the decision process, but they are noticeably reticent on how the informing takes place or whether evaluation is the most cost-effective way to do the informing. There is also mention in the literature of the political uses of evaluation in resource acquisition, but not many concrete examples of the strategy and tactics of using evaluations in this way. In general, R&D funders present positive evaluations to their sponsors to show that their overall volume of resources is being spent in a credible manner, but they do not demonstrate, nor do they necessarily want to, how evaluation is used to improve allocation or used seriously to switch resources into or out of different fields.

There is thus not much material to establish research evaluation craft based on actual practice or problem-solving during the execution of evaluations.

(1) *T. Ahn et al. "Some Statistical and DEA Evidence of Relative Efficiencies of Public and Private Institutions of Higher Learning," Socioeconomic Planning Science vol.22, 1988, pp.259-269. See

An application of data envelopment analysis (DEA) invented by the co-authors, Charnes and Cooper. DEA is a programming approach to measuring efficiency in organizations. See (11) below.

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[1]Department of Public Administration, Florida International University. This report is submitted in partial fulfillment of OTA Contract N3-2385.0

(2) J. Anderson et al., "On-line Approaches to Measuring National Scientific Output: A Cautionary Tale," Science and Public Policy, vol. 15, 1988, pp. 153-161.

(3) *W. B. Ashton and R. K. Sen, "Understanding Technology Change Using Patent Information," 1986, unpublished paper,

A clear explanation with examples of how patent citations may be used to make semi-strong inferences about technological developments and markets. Argues that companies have poor objective information on how they are progressing technologically or what technological strategies they should use for long-term business success and that systematic analysis of patents may help.

Argues that a highly cited patent is more technically relevant in advancing the current state-of-the art than a patent that is never cited. May have high business significance because competitors often try patent around a key development owned by another firm to maintain or capture market position. Limits are: thoroughness of patent searches: deliberately limited revelation of information in each patent, and the age of the patent.

(4) W. W. Ashton and R. K. Sen, "Using Patent Information in Business Planning-I, Research Technology Management, vol. 31, 1988, pp. 42-46.

(5) W. W. Ashton and R. K. Sen, "Using Patent Information in Business Planning-II," Research Technology Management, vol. 32, 1989, pp. 36-42.

(6) A. A. Araji, "Returns to Public Research Investment in the United States, Canadian Journal of Agricultural Economics, vol. 37, 1989, pp. 467-479.

(7) *R. W. Ashford et al., "The Capital-Investment Appraisal of New Technology: Problems, Misconceptions and Research Directions," Journal of the Operational Research Society, vol. 39, 1988, pp. 637-642.

Notes that traditional techniques of capital-investment appraisal are biased toward short-term gains and the status quo. Standard measures like NPV and IRR undervalue long-term benefits. Many benefits from new technology investments hard to quantify. Management control techniques compound the bias.

(8) W. Ashton et al., Patent Trend Analysis: Tracking Technology Change for Business Planning (Columbus, OH: Battelle Memorial Institute, 1985).

(9) *H. A. Averch, "Measuring the Cost-Efficiency of Basic Research: Input-Output Approaches," Journal of Policy Analysis and Management, vol. 6, 1987, pp. 342-362.

Examines the strengths, weaknesses and assumptions of the Irvine-Martin approach to assessing the research productivity of institutions by counting their absolute numbers of citations and publications. Suggests that there would be payoff in looking at information return per dollar of agency investment. Carries out the first known example of an efficiency comparison for basic research in NSF's behavioral science program.

(10) * _____, "Exploring the Cost-Efficiency of Basic Research Funding in Chemistry," Research Policy, vol. 18, 1989, pp. 165-172.

The first econometric study of research funding efficiency by a federal agency. Uses citations per dollar of research investment as the measure of efficiency. Shows that efficiency is determined by highly interactive variables such as investigators experience and the labor intensity of a project. Shows there is enormous variation in efficiency and that at least for the given sample, some factors thought to be important by the scientific community such as quality of department are not.

(11) ** _____, "The Practice of Research Evaluation in the United States," Evaluation of R&D--A Policymaker's Perspective, Department of Trade and Industry (London: Her Majesty's Stationery Office, 1988).

Presents a brief overview of the different methods of research evaluation in the United States. Discusses technical, political, and organizational problems in their use. Discusses some previously reported U.S. cases.

(12) **B. B. Bare and R. Loveless, A Case history of the Regional Forest Nutrition Research Project: Investments, Results and Applications (Seattle, College of Forest Resources, University of Washington, College of Forest Resources, 1985).

(13) *R. Barré, "A Strategic Assessment of the Scientific Performance of Five Countries, " Science and Technology Studies. vol. 5, 1987, pp. 32-38.

Uses aggregated citations produced by country and cluster analysis to decide who is ahead and behind in science.

(14) *B. L. Basberg, "Patents and the Measurement of Technological Change: A Survey of the Literature," Research Policy, vol. 16 (1987) pp. 131-141.

(15) *_____, "Patents and the Measurement of Technological Change," in K. Gronhaug and G. Kaufmann, Innovation: A Cross-Disciplinary Perspective (New York: Norwegian University Press, 1988).

Discusses patent statistics as technology indicators for a country and as a measure of diffusion of technology from country to country. Patent statistics believe

to reflect inventive activity. Discusses limits of patent indicators: whether patents are used commercially, the quality of patents, the differences among government patent offices. A small share of the total number of inventions are patented and this varies by economic sector. The patent share of inventions seems to be decreasing. Describes the trade secrecy alternative to patents.

Aggregated patent statistics do not distinguish between those leading to lead to basic innovations and those that lead to minor improvement. There exists considerable variation in patent policy and legislation. Quality may be variable over time and the relation between patents and inventions need not be constant. The article suggests that patent debate is not moving to closure and the same profs and cons are still being used. Although quality can be assessed it is highly subjective. Patent data have the advantage of long time series.

(16) *J. E. Beasley, "Comparing University Departments, Omega, vol. 18, 1990, pp. 171-183.

Uses a non-linear programming technique (DEA--data envelopment analysis) to assess the efficiency of British universities. DEA is a non-parametric technique and can be contrasted with statistical, production function approaches to efficiency.

(17) *D. N. Bengston, "Economic Evaluation of Agricultural Research," Evaluation Review, volume 9, 1985, pp. 242-262.

Bengston explains how economists evaluate research using consumers and producers surplus approaches.

(18) *D. N. Bengston and H. F. Kaiser, "Research Planning and Evaluation in the U.S. Forest Service," Evaluation Review, 12, 1988, pp. 276-290.

Reviews the use of consumers' surplus methods for evaluating research in the forest service. Contains a very good bibliography on other studies of returns to forestry research.

(19) F. Bilich, Science and Technology Planning and Policy (New York: Elsevier Science Publishers, 1989).

(20) P. Bisogno and G. Sirilli, "The Use of R and D Evaluation in Policy-Making in Italy," 1989, unpublished paper, presented to the ECE Seminar on Evaluation in the Management of R and D, April 3-7, 1989.

(21) J. Blanco et al., "Proposal of an Alternative Evaluation Program," 1989, unpublished paper, presented to the ECE Seminar on Evaluation in the Management of R and D, April 3-7, 1989.

Proposes that basic research be judged by relevance to social needs using exert judgment.

(22) J. T. Bonnen, "Historical Sources of U.S. Agricultural Productivity: Implications for R&D Policy and Social Science Research," American Journal of Agricultural Economics, vol. 65, 1983, pp. 958-966.

A critique of the standard literature on computing the rate of return to agricultural R&D. Notes that increases in productivity depend on complementary factors of production including institutional change. So attributing gains in productivity to agricultural R&D alone overstates the true marginal contribution of R&D.

(23) T. Braun et al, Scientometric Indicators: A 32-Country Comparative Evaluation of Publishing Performance and Citation Impact (Singapore: World Scientific Publishing Co., Ltd., 1985).

(24) R. Bud, "The Case of the Disappearing Caveat: A Critique of Irvine and Martin's Methodology," Social Studies of Science vol. 15, 1985, pp. 548-553.

(25) M. P. Carpenter et al. "Bibliometric Profile for British Academic Institutions: An Experiment to Develop Research Output Indicators," Scientometrics, vol 14, no 3-4, pp. 213-234.

(26) L. Christansen and J. K. Christansen, "An Analysis of Evaluations in the Nordic Countries, 1989, unpublished paper, presented to the ECE Seminar on Evaluation in the Management of R and D, April 3-7, 1989.

Analyzes 100 evaluations OF research in the Nordic countries. Argues for multiple methods. States that half were inadequate for decision making.

(27) D. E. Chubin, "Research Evaluation and the Generation of Big Science Policy, Knowledge vol. 9, 1987, pp. 254-277.

(28) * _____, "Designing Research Program Evaluations: A Science Studies Approach, Science and Public Policy, vol. 14, 1987, pp. 82-90.

Lays out rational procedures for action at each stage of research from initial funding onward so that e post evaluation will result in significant information.

(29) *Ciba Foundation Conference, The Evaluation of Scientific Research (New York: John Wiley & Sons, 1989).

Proceedings of a 1988 conference with familiar names in the science policy\evaluation field. Descriptions of techniques with few examples of concrete payoffs.

(30) G. A. Cole, The Evaluation of Basic Research in Industrial Laboratories (Cambridge, MA: Abt Associates, Inc.).

(31) H. M. Collins, "The Possibilities of Science Policy," Social Studies of Science vol. 15,1985, pp. 554-558.

(32) *H. R. Coward and J. J. Franklin, "Identifying the Science-Technology Interface," Science, Technology, and Human Values, vol. 14, 1989, pp. 50-77.

An attempt to measure the applied content of basic research by matching bibliometric data with patent data. Tries to identify areas of basic research that are "ready" to be applied. Also identifies people who produce science but also patent.

(33) R. Cordero, "The Measurement of Innovation Performance in the Firm: An Overview, Research Policy, vol. 19, 1990, pp. 185-192.

(34) S. E. Cozzens, "Exert Review in Evaluating Programs," Science and Public Policy, vol. 14, 1987, pp. 71-81.

(35) J. W. Creswell, Faculty Research Performance: Lessons from the Sciences and Social Sciences (Washington, DC: Association for the Study of Higher Education, 1985).

(36) D. Crouch et al., "Bibliometrics Analysis for Science Policy: An Evaluation of the United Kingdom's research Performance in Ocean Currents and Protein Crystallography, Scientometrics vol 9, 1986, pp. 239-267.

(37) *A. J. Czajowski and S. Jones, "Selecting Interrelated R&D Projects in Space Technology," IEEE Transactions on Engineering Management, vol.33, 1986, pp. 17-24.

A goal programming approach to project selection in the public sector.

(38) W. L. Currie, "The Art of Justifying New Technology to Top Management," Omega, vol. 17, 1989, pp. 409-418.

(39) *N. Danila, "Strategic Evaluation and Selection of R&D Projects," R&D Management, vol 19, 1989, pp.47-62.

Danila earlier surveyed 200 models for selecting R&D organizations [N. Danila, Strategies Technologiques. (Paris, FNEGE/IDMP, 1983)]. Here he presents a set of "families" for classifying the methods for evaluating R&D programs ex ante. However, many of the methods can be applied ex post. carried out.

The families are:(1) ratios: the worth of an R&D project is measured by a ratio between the benefit [savings, earnings, profit, cash flow] and the cost of R&D; (2) score index: index = expected benefit/cost. The expected benefit includes the ex ante subjective probability of success and cost sometimes includes the down stream capital investment. The index family also includes prospective NPV, IRR, and ROI; (3) programming: uses linear, non-linear, dynamic, or goal programming to determine allocation patterns; (4) matrices: measures the multi-dimensional consequences of research projects, for example, the scientific result and the impact of the results on industry; (5) systemic: factor analysis tries to identify the underlying factors involved in R&D selection. Projects can then be ranked using factor scores; (6) checklist: candidate projects checked against a set of criteria. The Kiefer check list, for example, has 56 criteria; (7) relevance trees: combine decision theory and operations research approaches; tables: multi-dimensional checklists; (8) multi-criterion: consensus: includes delphi and rules of thumb; (9) graphics; integrative family: examines scope, value, and potential implementation.

(40) Department of Trade and Industry, Evaluation of R&D--A Policymaker's Perspective (London: Her Majesty's Stationery Office, 1988.)

Proceedings and transcripts of the international workshop on assessment and evaluation in November 1988. Oriented to the processes of evaluation in different Western European countries.

(41) C. J. Doyle and M. S. Ridout, "The Impact of Scientific Research on UK Agricultural Productivity," Research Policy, vol. 14, 1985, pp. 109-116.

(42) W. A. Dejong, "Assessment and Evaluation of Output Quality at TNO," Paper presented at the International workshop on Assessment and Evaluation, Queen Elizabeth II Conference Centre, 17/18 November 1988, pp. 142-145.

(43) I. Dror, "Technology Innovation Indicators," R&D Management, vol. 19, 1989, pp. 243-249.

(44) L. Dwyer, "R&D Project Assessment as an Information and Communication Process," Prometheus, vol. 5, 1987, pp. 419-426.

(45) I. Feller, "Evaluating State Advanced Technology Programs," Evaluation Review, vol. 12, 1988, pp. 232-252.

(46) P. J. Finn, "Evaluation of the Crop Production Development Research Program, Canadian Farm Economics, vol. 21, 1987, pp. 19-27.

(47) S. J. Fitzsimmons, Strategic Evaluation of the Research Programs in the European Economic Community (Cambridge, MA: Abt Associates, Inc., 1985).

(48) G. Fox, "Is the United States Really Underinvesting in Agricultural Research, " American Journal of Agricultural Economics, vol. 67, 1985, pp. 806-812.

(49) *J. Jeffrey Franklin, "Selectivity in Funding: Evaluation of Research in Australia," Prometheus, vol. 6., No. 1, June 1988, pp.34-60.

Franklin reviews the research evaluation situation in Australia. He finds that the reasons for more emphasis on research evaluation resemble those in other countries--scarce resources, desire to link R&D performance to extra-scientific objectives, and evaluators claiming improved technology to evaluate. Franklin approaches evaluation from a rational decision making perspective, and lays out six axioms that evaluation should meet to be rational. He does not really consider the strategic uses of evaluation in obtaining the objectives of research funding bureaus.

The six axioms are:

1. Evaluation should be an on-going process in which evaluation is part of a cycle and connects with research planning and interim assessment
2. Participation by program officers and decision makers is as important as end product.
3. Evaluations must be designed to be policy relevant
4. Evaluations must be systematically planned, performed and documented
5. Evaluation involve systematic, unbiased collection of information.
6. Information gathering and analysis should be approached as a research design problem in itself.

(50) G. Friborg, "The Evaluation of National Schemes--with Single Organisations and within Collaborative Groups," Paper presented at the International workshop on Assessment and Evaluation, Queen Elizabeth II Conference Centre, 17/18 November 1988, in Department of Trade and Industry, pp. 78-85.

(51) M. Gibbons, "Methods for Evaluation of Research," International Journal of Institutional Management in Higher Education, vol. 9, 1985, pp. 79-85.

(52) C.S. Gilmor, "Comments on the Paper, 'A Reevaluation of the Contributions to Radio-Astronomy of the Nancay Observatory,' 4S Review, vol. 3, 1989, pp. 19-21.

(53) W. L. Giusti and L. Georghiu, "The Use of Co-Nomination Analysis in Real Time Evaluation of an R&F Programme, Scientometrics 14, 1986, pp. .

(54) *B. Gold, "Charting a Course to Superior Technology Evaluation," Sloan Management Review, vol.30, 1988, pp. 19-27.

Usual capital-budgeting techniques yield forecasts at variance with actual results, especially for innovative investments. Argues that evaluations of new technologies need to be made repeatedly for formative purposes and there must be rigorous post-evaluation review so as to improve ex ante estimates.

(55) L. Gougrnhrim, Comments on the Paper, 'A Reevaluation of the Contributions to Radio-Astronomy of the Nancay Observatory,' 4S Review, vol. 3, 1989, pp. 21-23.

(56) V. Grandis and G. Lewison, "Evaluation of European Community Programs in Information Technology and Biotechnology," Evaluation of R&D--A Policymaker's Perspective Department of Trade and Industry (London: Her Majesty's Stationery Office, 1988.)

(57) *P. E. Graves et al, Economics Departmental Rankings: Administrators Research Incentives, Constraints, and Efficiency, American Economic Review 72, 1982, pp. 1131-1141.

Graves et al. relate pages published per faculty member to salary levels, teaching hours, secretaries per faculty member, presence of teaching assistants, etc. They try a number of different model specifications, but the only variables that are significant are salaries and secretarial support.

(58) R. Gualtieri, "The Canadian Experience in Evaluating Regional Science and Technology Support Programmes," Evaluation of R&D--A Policymaker's Perspective, Department of Trade and Industry (London: Her Majesty's Stationery Office, 1988)

(59) _____, "Evaluation of R&D in Canada," Evaluation of R&D--A Policymaker's Perspective, Department of Trade and Industry (London: Her Majesty's Stationery Office, 1988).

(60) *K. Guy and L. Georghiou,"Real-Time Evaluation and the Management of Mission-Oriented Research: The Evaluation of the Alvey Program: aims, achievements and Lessons, 1989, unpublished paper, presented to the ECE Seminar on Evaluation in the Management of R and D, April 3-7, 1989.

Takes a process evaluation approach. Argues real-time evaluation with feedback can improve the conduct of current programs.

(61) J. Haygreen et al., "The Economic Impact of Timber Utilization Research," Forest Products Journal, vol. 36, 1986, pp. 12-20.

(62) P. Hare et al., "Evaluation of the Involvement of the United Kingdom in Esprit," Paper presented at the International workshop on Assessment and Evaluation, Queen Elizabeth II Conference Centre, 17/18 November 1988, in Department of Trade and Industry, pp. 100-106.

(63) *P. Hare and G. Wyatt, "Modelling the Determination of Research Output in British Universities," Research Policy, vol. 17, 1988, pp. 315-328.

Aggregates bibliometric indicators to university level to make inferences about relative performance. Since the reasons for differential performance are not known, policy inferences are problematic.

(64) P. Healy, H. Rothman, and P. K. Hoch, "An Experiment in Science Mapping for Research Planning," Research Policy, vol. 15, 1986, pp. 233-251.

(65) E. K. Hicks and W. Callebaut. Evaluative Proceedings: 4S/EASST (Amsterdam: SISWO Pulikatie, 1989).

(66) *R. E. Eldon and C. M. Devine, "Government's Research and Evaluation Gap," Public Relations Review, vol. 11, 1985, pp. 47-56.

A survey of 131 top federal information officers shows the gap between the rhetoric about the importance of research and evaluation in decision making and their actual use. Gives a description of the discrepancies between theory and practice in government information operations. Government information officers seem to lack understanding or training in research and evaluation. The results of this survey are consistent with the view that research and evaluation are more important symbolically than substantively and with the view that government agencies and decision makers rationally demand much more systematic information than they want to use.

(67) *J. D. Hodgdon, Methods for the Strategic Evaluation of Research Programs: The State of the Art (Cambridge, MA: Abt Associates Inc, 1985).

An assessment of the weak state of research evaluation in 1985. The same methods and issues still hold in 1990.

(68) T.D. Hogan, "The Publishing Performance of U.S. Ph.D. Programs in Economics During the 1970's," Journal of Human Resources, vol. 21, 1986, pp. 216-229.

(69) J. Irvine, Evaluating Applied Research: Lessons from Japan (London: Pinter, 1988).

(70) _____, "Evaluation of Scientific Institutions: Lessons from a Bibliometric Study of UK Technical Universities," in Ciba Foundation Conference, The Evaluation of Scientific Research (New York: John Wiley & Sons, 1989).

Concludes, not surprisingly, given the author's well known advocacy of bibliometrics, that aggregate bibliometric data can be used to discern differences in performance among universities with the same mission. Does not address the issue of differential access to resources as a cause of differences in performance, but does note that resource flows in and research out have to be more closely related.

(71) *J. Irvine et al, "Assessing Basic Research: Reappraisal and Update of an Evaluation of Four Radio Astronomy Observatories," Research Policy, vol. 16, 1987, pp. 213-227.

(72) J. Irvine and B. R. Martin, "Assessing Basic Research: The Case of the Isaac Newton Telescope," Social Studies of Science, vol 13, 1983, pp. 49-86.

(73) *J. Irvine and B. R. Martin, Research Foresight: Creating the Future (The Hague, Netherlands Ministry of Education and Science, 1989).

A report to the Dutch Ministry of Science on the alternative means of predicting research payoffs used by different countries. Strong on describing the processes countries use. Weak on evaluating whether these processes have any validity or actually deliver "foresight."

(74) J. Irvine et al., "Assessing Basic Research: Reappraisal and Update of an Evaluation of Four Radio Astronomy Observatories," Research Policy, vol. 16, 1987, pp. 213-227.

(75) P. M. Jakes, "Research Evaluation in the U.S. Forest Service: Opinions of Research Managers," Research Policy vol. 17, 1988, pp. 283-292.

(76) P. M. Jakes and E.C. Leatherberry, Alternative Approaches to Forestry Research Evaluation: an Assessment (St. Paul: U.S. Department of Agriculture Forest Service, 1986).

(77) G. Lockett and M. Stratford, "Ranking of Research Projects: Experiments with Two Methods," Omega, vol. 15, 1987, pp. 395-400.

(78) *H. F. Moed, W.J.M Burger, J.G. Frankfort, and A.F.J. Van "The Use of Bibliometric Data for the Measurement of University Research Performance." Research Policy, vol.14, 1985, pp.131-149.

Reports on use of bibliometric data to change resource allocations in Dutch universities. The authors are among the more prominent believers in bibliometrics and thus do not really address their limits in resource allocation questions.

(79) M. R. Jalongo, "Faculty Productivity in Higher Education," The Educational Forum, vol. 49, 1985, pp. 171-182.

(80) J. King, "A Review of Bibliometric and Other Science Indicators and their Role in Research Evaluation," Journal of Information Science, vol. 13, 1987, pp. 261-276.

(81) ***R. N. Kostoff, "Evaluation of Proposed and Existing Accelerated Research Programs of the Office of Naval Research," IEEE Transactions on Engineering Management, vol. 35, 1988. pp. 271-279.

One of the very few actual accounts of a research evaluation by a federal agency. ONR used experts on research, experts on translating research into weapons systems, and actual users. Used structured check lists and questions to get at value of research. Carried out both formative and summative evaluations to the point where 40 percent of ONR activity has been evaluated. Similar to the major DOE evaluation of basic research in the early 1980's.

(82) C. E. Kruytbosch, "Some Social and Organizational Characteristics of Breakthrough Science: An Analysis of Major Innovations in Four Fields of Science, 1950-1976." 1978. Paper presented at the I World Congress of Sociology, Uppsala, Sweden.

(83) I. Karatzas and G. Lewison, Evaluation of Scientifically-led Programmes, 1989, unpublished paper, presented to the ECE Seminar on Evaluation in the Management of R and D, April 3-7, 1989.

(84) J. King, "The Use of Bibliometric Techniques for Institutional Research Evaluation: a Study of Avian Virology, Scientometrics vol. 14, 1988, pp. 295-314.

(85) J. Krige and D. Pestre, "A Critique of Irvine and Martin's Methodology for Evaluating Big Science," Social Studies of Science, vol. 15, 1985, pp. 525-539.

(86) P. Laredo, "The Assessment of National Schemes; Problems Associated with Implementation: Discussion of the French Experience," Evaluation of R&D--A Policymaker's Perspective, Department of Trade and Industry (London: Her Majesty's Stationery Office, 1988.)

(87) T. Lazlo, Management and Evaluation of Central R and D programmes in Hungary, 1989, unpublished paper, presented to the ECE Seminar on Evaluation in the Management of R and D, April 3-7, 1989.

(88) L. Leydesdorff and P. van der Schaar, "The Use of Scientometric Models for Evaluating National Research Programs," Science and Technology Studies, vol. 5, 1987, pp. 22-31.

(89) J. M. Logsdon and C. Rubin, An Overview of Federal Research Evaluation Activities. (Washington, DC: George Washington University, 1985)

Describes the evaluation process in several federal agencies.

(90) H-P. Lorenzen, "Formulation of Aims and Evaluation using the Example of the Pilot Scheme 'Support for New Technology-based Firms' of the BMFT in Germany.' Evaluation of R&D--A Policymaker's Perspective, Department of Trade and Industry (London: Her Majesty's Stationery Office, 1988.)

(91) *T. Luukkonen-Gronow, "Scientific Research Evaluation: A Review of Methods and various Contexts of Their Application," R&D Management, vol. 17, 1987, pp. 207-221.

A critical explanation of peer review, questionnaires, qualitative methods, case studies. Discusses use in policy making. No standardized set of evaluation techniques exist that can be used in a routine manner. Need to account for the unintended consequences of evaluations.

(92) *,**T. Luukkonen-Gronow and B. Staehle, "Quality Evaluations in the Management of Basic and Applied Research," unpublished paper, presented to the ECE Seminar on Evaluation in the Management of R and D, April 3-7, 1989.

Reports on the utilization of 101 research program evaluations in the natural sciences, medicine, and technology. These evaluations were conducted in the Nordic countries between 1976-1988. Notes that little information exists on how program evaluations are used and that received opinion varies between low use to providing powerful methods of control by decision makers.

In general, the demand for evaluation was driven by a need to increase accountability in a period of rising costs and to legitimate increases in research funding. Evaluators claimed that their work would guarantee the quality of research and orient it to scientifically promising areas.

Generic problems identified across the 101 cases included too little mobility of researchers, too few international contacts, inflexible career structure, unbalanced supply of qualified research staff, short term funding decisions, and uncoordinated instrument purchases.

This study distinguishes between decisions "use" and impacts. Use refers to employment in the decision process. Use may be instrumental, to provide information for decision making. It may be persuasive, attempting to convince parties to a dispute, or it may be conceptual, helping to define or formulate new questions. Impact refers to the actual change or modification of programmes, personnel deployment, funding decisions, or policy setting. Most of the 101 evaluations were used in one of the three senses. However, because of the complexity of use and the multiple audiences for evaluations, many had no impact. That is, use was not followed by concrete measures of implementation.

The authors note that impact is not always well documented and that references to evaluations in policy debates may have no bearing on actual impacts. Also, evaluations may only be one factor in decision making and decisions turn on other factors.

Notes that in the Scandinavian countries the evaluations are public documents and available to any one. Open access creates concerns about extrinsic limits on research and political control. However, even though open, very few people knew much about the evaluations their own organizations commissioned, and decision making bodied paid little attention to implementation.

The authors do note that on occasion positive evaluations result in relatively large allocations of money, as was the case for the hydrobiology program in Finland. Notes however that even resource allocation decisions are marginal.
On the average, evaluations that are relevant will have more use and impact. However, the higher the level of commission, the less relevance there was. High level bodies frequently have multiple, obscure purposes. Relevance in turn depends on good communication between evaluators and decision makers. The user organization must have its own internal invisible college. Use and impact also depend on credibility. The credibility becomes a function of who selects the reviewing peers. Those evaluated negatively often find fault with evaluations,

Necessary conditions for successful evaluations include:
relevance to a need for information; sound methods, effective communication, provision of users with "ammunition," political support.

The authors go on to raise the cost effectiveness of evaluations noting that they can have negative consequences. These include tot competitive an atmosphere, emphasis on short term results and one sided publication structures.

(93) *E. Mansfield, "The Social Rate of Return from Academic Research," 1988, unpublished manuscript.

Establishes the social rate of return to world academic research by asking industrialists about technological breakthroughs made possible by that research.

(94) *B. R. Martin and J. Irvine, "Evaluating the Evaluators: A Reply to our Critics," Social Studies of Science, vol. 15, 1985, pp. 558-575.

Martin-Irvine note that despite the technical concerns of their critics, decisions need to be made anyway, and some imperfect data is better than no data in decision making.

(95) _____, An International Comparison of Government Funding of Academic and Academically Related Research (Brighton, UK: Science Policy and Research Evaluation Group, 1986).

Constructs the total flow of resources into different fields of academic research. Possible to compare allocations across countries and make crude inferences of the value countries assign to different fields of inquiry.

(96) Martin, B.R. et al. "A Re-Evaluation of the Contributions to Radio Astronomy of the Nancay Observatory, 4S Review, vol. 3, 1985, pp. 14-18.

(97) Jean-Francois Miquel, "Indicators to Measure Internalization of Science," unpublished paper 1989.

(98) L. Massimo and P. Kerr, The Evaluation of R and D Programmes of the Commission of the European Communities, in Evaluation of R&D--A Policymaker's Perspective, Department of Trade and Industry (London: Her Majesty's Stationery Office, 1988.)

(99) G. F. Mechlin and D. Berg, " Evaluating Research--ROI is not Enough," in K. Gronhaug and G. Kaufmann, Innovation: A Cross-Disciplinary Perspective (New York: Norwegian University Press, 1988).

Argues that conventional ROI inhibits innovation since it does not count significant benefits that derive from a corporate research capability in the long run. Technological innovation takes a long time and so there is a temporal mismatch between short-run ROI and the natural pace of innovation. ROI does not take account of the fact that projects with negative ROIs nay yet contribute valuable information to the firm. Suggest that period reviews would be useful, that returns over the entire product life cycle be attributed to R&D, that product line contributions would be a good, complementary measure.

(100) J. Metters, "Assessment in the UK Department of Health and Social Security Research," Evaluation of R&D--A Policymaker's Perspective, Department of Trade and Industry (London: Her Majesty's Stationery Office, 1988.)

(101) F. Moisan, "Appraisal of a Research Programme and its Consequences: The AFME Experience," Evaluation of R&D--A Policymaker's Perspective, Department of Trade and Industry (London: Her Majesty's Stationery Office, 1988.)

(102) **H. F. Moed and A. F. J. van Raan, "Critical Remarks on Irvine and Martin's Methodology for Evaluating Scientific Performance," Social Studies of Science vol. 15, 1985, pp. 539-547.

A technical critique of the Irvine-Martin publication count approach to research evaluation by two prominent Dutch practitioners.

(103) T. K. Moran, "Research and Management Strategies for Integrating Evaluation Research in Agency Decisionmaking," Evaluation Review, vol. 11, 1987, pp. 612-630.

(104) F. Narin, "Bibliometric Techniques in the Evaluation of Research Programs, Science and Public Policy, vol. 14, 1987, pp.99-106.

(105) F. Narin et al., "Patents as Indicators of Corporate Technological Strength," Research Policy, vol. ,1986, pp. .

(106) F. Narin and D. Olivastro, Identifying Areas of Leading Edge Japanese Science and Technology: First Interim Report, "Activity Analysis Using SIC Categories and Scientific Subfields" (Cherry Hill, NJ: Computer Horizons, Inc, 1986).

(107) A. J. Nederhoff and A. F. J. van Raan. An International Interview Round on the Use and Development of Science and Technology Indicators (Leiden: University of Leiden, 1988).

Reports on a series of interviews with science administrators West Germany, the United Kingdom, France, Canada, and the United States. Qualitative, holistic discussions and overviews by peers characteristic of a number of countries in Western Europe. However, use of quantitative indicators in policy not at all characteristic anywhere. (HA note: Research evaluators everywhere seem to have a substantively "rational" model in mind for science policy and resource allocation. Thus they cannot understand the lack of use. However, the use of indicators can cut against politically and bureaucratically rational policy making.)

(108) R. Neimeyer and W. R. Shadish, Jr. "Optimizing Scientific Validity: Toward an Interdisciplinary Science Studies,: Knowledge: Creation, Diffusion, Utilization, vol. 8, No.3, March 1987, pp. 463-485.

(109) Nordic Science Policy Council, Evaluation of Research: Nordic Experiences (Copenhagen: Nordic Science Policy Council, 1986).

(110) NSF Evaluation Staff, Office of Audit and Oversight, The NSF Post-Performance Evaluation Study. 84-2. (NSF, Washington, 1984).

(111) NSF Evaluation Staff, "Post-Performance Evaluation of Behavioral and Neural Sciences, 1985, unpublished manuscript.

Reports the outcome of an actual evaluation in NSF. Data later used in reference (3). Does not report use NSF officials made of the evaluation. However, it served to legitimate NSF's prior beliefs that it funds good work. Mentioned in passing in NSF budget negotiations with OMB.

(112) OECD, Evaluation of Research: A Selection of Current Priorities. (Paris, OECD, 1987).

(113) E. Ormala, "Evaluation for Selection in Technical R and D,"1989, unpublished paper, presented to the ECE Seminar on Evaluation in the Management of R and D, April 3-7, 1989.

(114) *OTA, Research Funding as Investment: Can We Measure the Returns (Washington, DC: OTA, 1986).

A broad survey of the different methods used to establish returns to research. It concludes that it will be most difficult to measure returns credibly.

(115) P. G. Pardey, "The Agricultural Knowledge Production Function: An Empirical Look," Review of Economics and Statistics, vol. 71, 1989, 453-461.

(116) P. G. Pardey and B. Craig, "Causal Relations between Public Sector Agricultural Research Expenditures and Output, American Journal of Agricultural Economics, vol. 71, 1989, pp. 9-19.

(117) K. Pavitt, "Patent Statistics as Indicators of Innovative Activities," Scientometrics, vol. 7, 1985, pp. 77-99.

(118) D. C. Phillips and J. Turney, "Bibliometrics and UK Science Policy," Scientometrics, vol. 14, 1988, pp. 185-200.

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